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MICHIGAN STATE UNIVERSITY

AGRICULTURAL EXPERIMENT STATION

EAST LANSING

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THE QUARTERLY BULLETIN

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MICHIGAN STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION
EAST LANSING

L. M. TURK, DIRECTOR
R. J. ALDRICH, ASSISTANT DIRECTOR
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CORN ROOT DEVELOPMENT

By H. D. FOTH, K. L. KINRA and J. N. PRATT

DEPARTMENT OF SOIL SCIENCE

THE DEVELOPMENT OF CORN ROOTS was studied by Weaver[1] over 30 years ago. He described the number, size, and position of the roots exposed in trenches at five weeks, eight weeks, and when the plants had attained maturity.

The weight of corn roots was determined by Long[2] in Tennessee on the 43rd, 68th and 110th days after planting. Roots had reached a depth of 12 inches and had attained 21 percent of their weight at maturity by the 43rd day. Root weight more than tripled during the next 25 days so that on the 68th day, the weight was equal to 74 percent of the weight at maturity. Plants were grown on the well-drained Lintonia silt loam soil.

It has been recognized that additional information on root behavior would be useful in designing and interpreting results of tillage and fertilizer experiments. For this reason, a quantitative study was made of the development of corn roots in the field. The results of such a study are presented in this paper.

PROCEDURE

An early maturing hybrid (Michigan 250, 85-day) was planted in 42-inch rows on June 5, 1959. The plant population approximated 18,000 to 19,000 plants per acre. One thousand pounds per acre of 12-12-12 fertilizer was applied 9 inches deep on the plow sole in the fall of 1958 and 500 pounds per acre of 5-20-20 was broadcast before planting, in the spring. One hundred pounds per acre of 5-20-20 was applied at planting time using a split boot applicator. One shallow cultivation was made on June 22.

Conover loam was the dominant soil type in the study area. It is an

[1] Weaver, J. E. (1926). *Root Development of Field Crops*, McGraw-Hill Co., Inc. 291 pp.
[2] Long, O. H. (1959). Root studies on some farm crops in Tennessee. Tenn. Agr. Expt. Sta. Bul. 301, 41 pp.

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imperfectly drained, moderately dark-colored, Gray-Brown Podzolic soil developed from loam parent material. Conover soils are the imperfectly drained members of the catena which includes the well-drained Miami soils and poorly-drained Brookston soils. The profile is considered to be free of layers or horizons that are unfavorable for root growth. A profile description of Conover loam taken in the immediate area is as follows:

A_p	0-9″	Loam; very dark gray (10YR 3/1, moist); weak, fine to medium granular structure; friable; slightly acid to neutral.
A_{2g}	9-15″	Loam; pale brown (10YR 6/3, moist), mottled with yellowish brown (10YR 5/4 to 5/8, moist); weak, medium to coarse, subangular blocky structure; friable; slightly acid to neutral.
B_{2g}	15-33″	Clay loam; pale brown (10YR 6/3, moist), mottled with yellowish brown (10YR 5/4 to 5/4, moist); weak, medium to coarse, subangular blocky structure; slightly plastic; slightly acid to neutral.
C_g	33″+	Loam; light gray (10YR 7/2, moist), mottled with pale brown (10YR 6/3, moist) and yellowish brown (10YR 5/8, moist); stratified to massive; friable; calcareous.

Root samples were obtained on 10 dates in the summer of 1959. Samples on the first three sampling dates were obtained by driving metal samplers vertically in the soil to a maximum depth of 1 foot. Samplers ranging in size from 8″ x 12″ to 12″ x 21″ were used, depending upon the extensiveness of the root system.

On the fourth and subsequent sampling dates, a pit was dug perpendicular to the row so that a 4-inch thick slice of soil could be obtained directly opposite a corn plant. The samplers were 21 inches wide and extended to the middle of the 42-inch row. The depth of sampling was increased as the root system developed.

The 4-inch thick sample was vertically sectioned into 6-inch layers. Laterally, it was sectioned 0 to 3, 3 to 9, 9 to 15, and 15 to 21 inches from the plant. These sectioned samples were washed with water and the roots were recovered on a wire screen. Tweezers were used to separate roots from foreign matter. The roots were first photographed on black velvet, and then oven dried and weighed.

The soil was sufficiently moist throughout the sampling period so that samples were easily obtained without wetting the soil. Rolling of the leaves was never observed and it was assumed that plant growth was not limited by a deficiency of moisture. Conversely, there was no indication that excess moisture interfered with plant growth. Corn on adjacent plots yielded 90 to 100 bushels per acre and was representative of the conditions where the roots samples were collected.

RESULTS AND DISCUSSION

The percentage distribution of the roots laterally and vertically through the sampling period is shown in Figures 1 and 2. The weight of roots in the various zones and layers of the soil increased throughout the period (Table 1).

Lateral Development

Extensive lateral root growth occurred during the early part of the growing season. The roots had extended laterally into the 15- to 21-inch zone by the 27th day. On this date, root development had

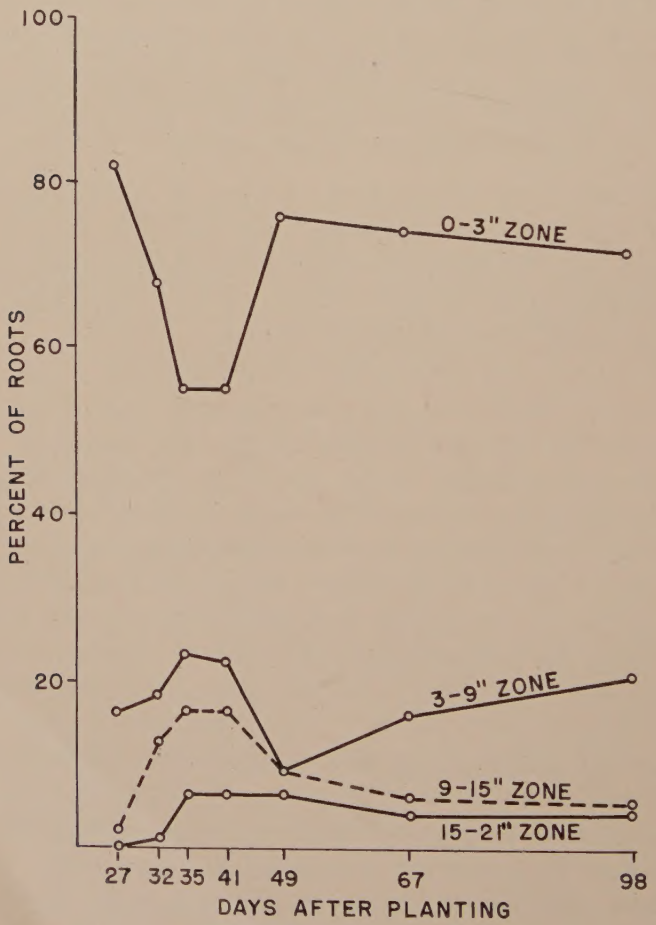

Fig. 1. The percentage distribution of roots laterally between the 27th and 98th days.

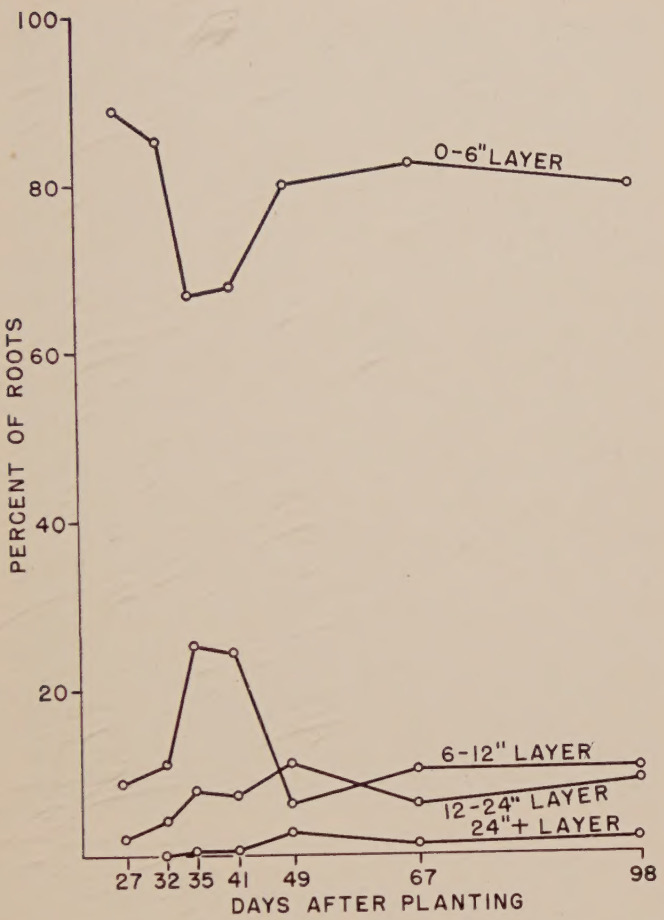

Fig. 2. The percentage distribution of roots vertically between the 27th and 98th days.

occurred predominately in a lateral direction in the top 6 inches of the soil and, to a lesser extent, vertically underneath the plant. Eighty-nine percent of the roots were in the top 6 inches (Figure 2).

Seventeen percent of the roots in this layer were at a distance of 3 to 21 inches from the plant. This indicates the amount of root pruning that could occur at this time by cultivation. Studies to determine the extent to which the root system re-develops, if pruned by cultivation early in the season, might be useful.

The trend toward lateral root growth early in the season is also shown in Figure 3. Less than 10 percent of the root weight was found

TABLE 1—Corn root and shoot data for seven sampling dates during 1959

Date	Days after planting	Weight of oven-dry roots in grams(*a*)											Percent of roots	Roots per plant, gms. (*d*)	Shoot			Shoot-root ratio
		Inches from base of plant										Total			Weight gms. oven dry	Percent	Height, inches (*e*)	
		Laterally, inches				Vertically, inches												
		0-3	3-9	9-15	15-21	0-6	6-12	12-18	18-24	24-30	30-36	36-42						
July 2....	27	.53	.10	.01	(*b*).01	.58	.06	.01	...	...	...	...	.65	6	1.6	8	2	34	5.0
July 7....	32	.66	.17	.13	.01	.83	.11	.03	(*b*).01	...	...	...	.97	8	2.4	14	4	40	5.8
July 10 ..	35	1.15	.49	.35	.12	1.42	.53	.07	.08	.01	...	...	2.11	18	5.2	37	10	52	7.1
July 16(*c*)	41	1.53	.62	.45	.18	1.90	.65	.20	.02	.01	(*b*).01	...	2.78	24	7.0	81	22	66	11.6
July 24 ..	49	4.89	.62	.63	.42	5.21	.42	.39	.33	.15	.06	...	6.56	57	16.3	99	27	82	6.1
Aug. 11..	67	7.66	1.67	.63	.45	8.68	1.05	.34	.27	.05	.01	.01	10.41	90	26.0	204	55	112	8.0
Sept. 11..	98	7.97	2.22	.83	.51	9.17	1.17	.60	.45	.11	.01	.02	11.53	100	28.8	370	100	114	12.8

(*a*) In 4" x 21" x 42" volume of soil opposite the plant and perpendicular to the row.
(*b*) Roots were present but weight was less than .01 gram.
(*c*) Average of 9- and 18-inch plowing depths.
(*d*) Based on the assumption that 20 percent of the root weight occurred in the middle 4 inches between adjacent plants, 8 inches apart.
(*e*) Measured to tip of longest leaf or tassel, whichever was the greatest.

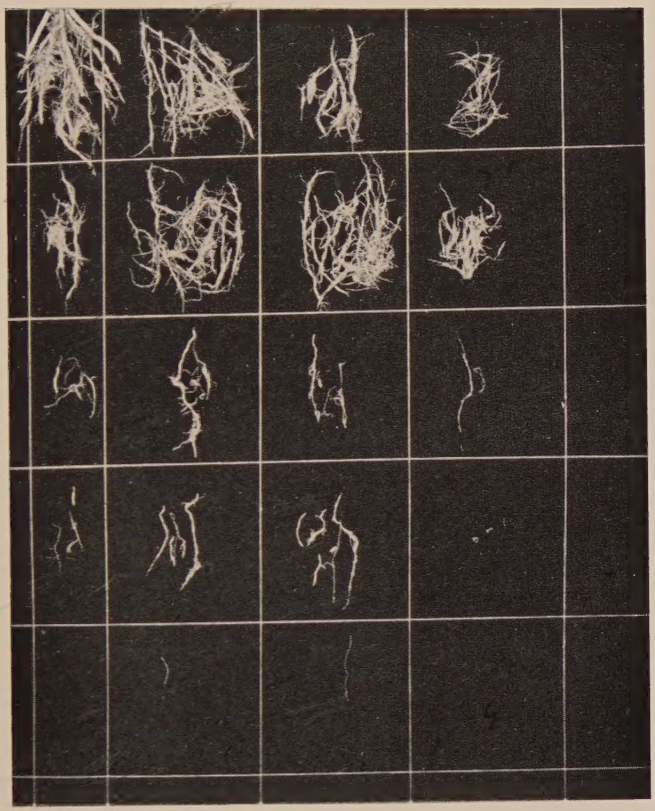

Fig. 3. Root distribution on the 35th day in a 4-inch thick slice of soil directly opposite the plant and perpendicular to the row. Zones left to right are 0 to 3, 3 to 9, 9 to 15, and 15 to 21 inches. Layers vertically are 6-inch intervals.

below a depth of 1 foot on the 35th day. The above ground portion of the corn plant from which the roots were sampled is shown in Figure 4.

All or most of the roots exist in the zone 0 to 3 inches from the plant when it is several days old. Later, roots elongate and grow into areas more distant from the plant. Root growth is more rapid, relatively speaking in the more distant soil from the 27th to the 35th day. This is shown in Fig. 1 by a percentage decrease in the amount of roots in the 0- to 3-inch zone while an increase occurred in other zones.

Little or no difference in the percentages of roots existed on the 35th and 41st day. Development of brace roots on the lower stem had begun by the 41st day. Their development in the 0- to 3-inch zone accounts for the sharp increase in the percentage of roots in

this zone between the 41st and 49th days. Later, brace root development in the 3- to 9-inch zone occurred more rapidly, relatively speaking, than in the 0- to 3-inch zone. This caused an increase in the percentage of roots in the 3- to 9-inch zone and a decrease in the 0- to 3-inch zone after the 49th day (Fig. 1.)

The percentage of roots in the 9- to 15- and 15- to 21-inch zones decreased after the 41st day. This was associated with a lack of brace root development in these zones.

Vertical Development

The curves for vertical root development are similar to those of lateral development (Fig. 2). They can be similarly explained so a

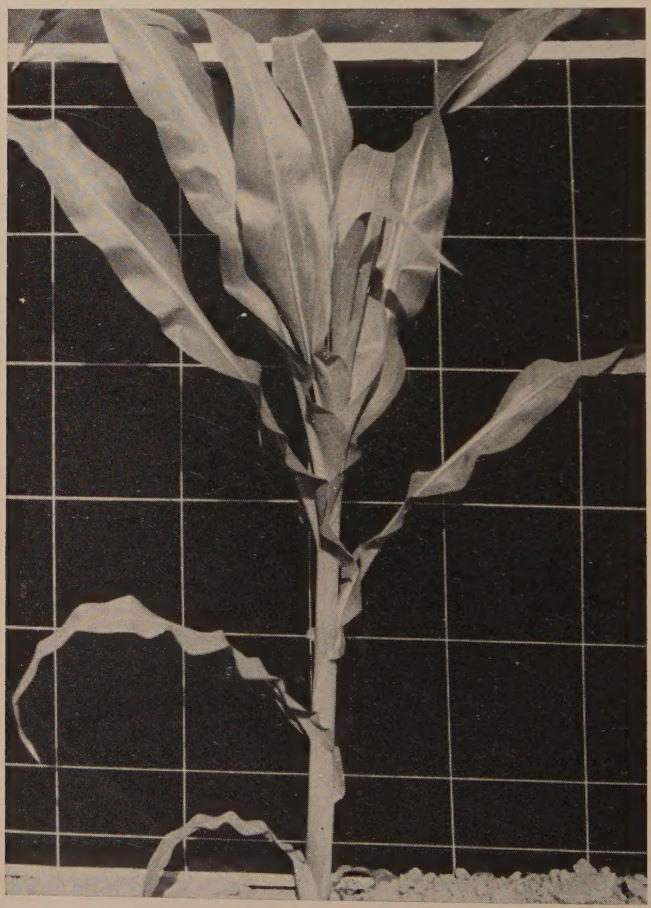

Fig. 4. Corn plant on 35th day. The background board is 39 inches tall.

detailed explanation is not needed. Brace root development occurred in both the 0- to 6- and 6- to 12-inch layers. Increases in the percentages of roots below a depth of 12 inches occurred between the 67th and 98th days.

Nature of Root Development

A given soil volume appeared to have been "filled" with roots before root growth proceeded rapidly in areas more distant from the plant. Certain "leader" roots quickly extended out into regions "distant" from the plant but rapid growth in these areas did not occur until the soil volume closer to the plant had been "filled" to a large extent. The weight of roots, in areas so "filled," continued to increase but at a greatly reduced rate. For instance, in the 9- to 21-inch zone of the upper foot of soil, the weight of roots on the 41st day was 72 percent of that found on the 98th day. The weight of roots in this zone was the same on both the 67th and 98th days.

The "filling" tendency in a lateral direction is shown by the fact that on the 32nd day there were 18 and 13 percent of the total root weight in the 3- to 9- and 9- to 15-inch zones, respectively, and only 1 percent in the 15- to 21-inch zone (Fig. 1). Maximum rate of growth in these three zones also occurred during successive sampling intervals.

Vertical root growth also occurred as a "filling" phenomenon. On the 35th day the amount of roots in the 6- to 12- and 12- to 18-inch layers were 25 and 4 percent, respectively (Fig. 3).

The roots grew downward as a "front" in the soil below 1 foot after about the 35th day. Their weight increased more rapidly in the zone 0 to 9 inches from the plant than in the zone 9 to 21 inches from the plant. On the 41st day, there were 69 and 31 percent of the roots in the 0- to 9- and 9- to 21-inch zones, respectively, below 1 foot in depth. These percentages were 56 and 44, respectively, on the 67th day. The percentages were 51 for the 0- to 9-inch zone and 49 for the 9- to 21-inch zone on the 98th day.

The root distribution on the 67th day is shown in Fig. 5.

The moisture content of the soil was determined on the 41st day. The rainfall had been considerably below average up to this date and early planted corn in the vicinity had already exhibited drought symptoms. Rainfall following this date was abundant and frequent as shown in Table 2. Therefore, differences in soil moisture at various locations in the soil were probably at a maximum.

The moisture data in Table 3 represents the average of samples

taken where the soil was plowed 9 and 18 inches deep. The data show a trend for the moisture content of the soil to increase with an increase in the lateral distance from the plant. Thus, the pattern of moisture removal parallels that found for root development.

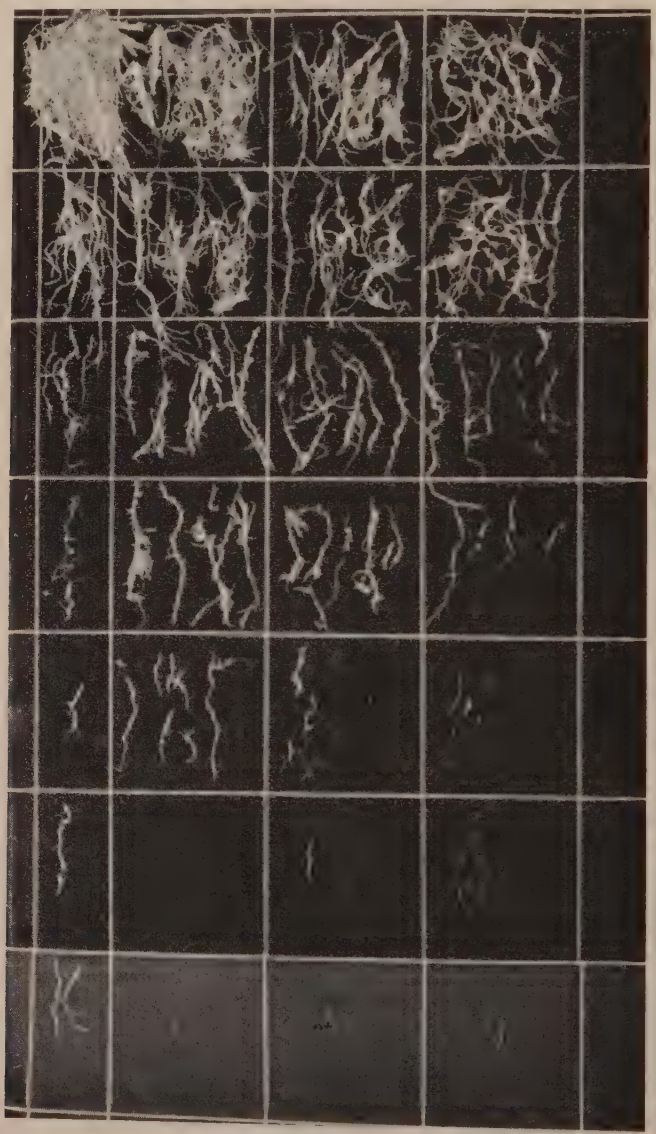

Fig. 5. Root distribution on the 67th day in a 4-inch thick slice of soil opposite the plant and perpendicular to the row. Zones left to right are 0 to 3, 3 to 9, 9 to 15, and 15 to 21 inches. Layers vertically are 6-inch intervals.

TABLE 2—Inches of recorded rainfall at East Lansing for the summer of 1959

June		July		August		September	
Date	Amount	Date	Amount	Date	Amount	Date	Amount
1	.09	1	.48	4	.08	2	.64
11	.39	9	.05	7	1.63	9	.12
15	.03	18	.47	11	.05	21	.80
22	.17	20	.45	15	.77	23	.51
24	.05	23	2.71	16	.90	24	.08
25	.34	29	.71	17	.07	26	.41
26	.20	30	.80	23	.12	27	.24
29	.25			26	.78	28	.30
30	.08			27	.71	29	.21
				28	.02		

These results are also in agreement with the work of Russell *et al.*[3] They found that moisture was first extracted directly underneath the corn plant and then extraction occurred in successive zones laterally from the plant. When most of the available moisture in the upper layer of soil was removed, the pattern was repeated in the next and successively deeper layers as the summer progressed. It seems reasonable that the point when most of the available moisture had been removed, as determined by Russell *et al.*,[3] coincides with the point when considerable "filling" of the soil with roots had occurred as described in this study (excluding areas subject to brace root development).

Limited overlap of root systems between the rows would be ex-

[3] Russell, M. B., F. E. Davis and R. A. Bair (1940). The use of tensiometers for following soil moisture conditions under corn. Jour. Amer. Soc. Agron. 32 922-930.

TABLE 3—Percent soil moisture laterally and vertically from the base of the corn plant on the 41st day. Average of plots plowed 9 and 18 inches deep

Depth, inches	Distance from plant laterally, inches			
	0-3	3-9	0-15	15-21
0-6.....	11.9	12.3	13.3	13.5
6-12.....	12.5	13.3	13.4	15.9
12-18.....	12.2	12.5	12.4	13.1
Average....	12.2	12.7	13.0	14.2

pected in the upper foot of soil on the basis that most of the available water in the middle of the row would have been extracted by the time the roots from two adjacent rows met. However, subsequent rewetting of the soil could be expected to cause some additional extension of the roots beyond the mid-point between the rows.

The curve which represents root growth through the summer is sigmoidal in nature. Fourteen, 76, and 10 percent of the root growth occurred in the first 32, the next 35, and the last 31 days, respectively, of the 98-day sampling period (Table 1). Three-fourths of the root growth occurred during the middle 35-day period.

On the 98th day, only 2 percent of the roots occurred below a depth of 2 feet. This suggested that the plant may not be effectively utilizing the soil moisture and nutrients below this depth.

Additional samples were collected mid-way between adjacent plants at maturity. The root weight in the 4-inch thick slice of soil between adjacent plants was found to be one-fourth as large as the root weight in the sample collected directly opposite the plant. The total root weight per plant, as given in Table 1, was calculated on this basis. The total root weight per acre was 1,186 pounds on the 98th day and was based on the assumption that plants were 8 inches apart in 42-inch rows.

Root Development Versus Shoot Development

Complete root systems were obtained on June 16, 19, and 26. The weight of roots per plant was .08, .17, and .72 grams, respectively. Corresponding shoot weights were .18, .38, and 2.58 grams. The shoot-root ratio during this period ranged from 2.2 to 3.6. The corresponding heights of the plants were 7, 10, and 19 inches, as measured to the tip of the longest leaf.

Root growth occurred more rapidly, relatively speaking, than shoot growth early in the season. Eighteen percent of the root growth for the season had been completed by the 35th day, versus only 10 percent for the shoot. Shoot weight increased very rapidly between the 35th and 41st days so that the percentages became nearly the same, being 24 and 22. This phenomena is expressed in the large increase in the shoot-root ratio between the 35th and 41st day (Table 1).

Growth of the brace root system between the 41st and 49th days resulted in an increase in root weight equal to 33 percent of the

final weight. Top growth was considerably arrested during this period as it increased only 5 percent. The shoot-root ratio declined from 11.6 to 6.1 during this eight-day period.

The remainder of the season was characterized by relatively greater increases in shoot growth than root growth. The shoot-root ratio increased to 12.8 by the 98th day.

SUMMARY

Patterns for corn root development laterally and vertically have been presented.

Early root development showed a prominent lateral growth up to about the 35th day in the upper foot of soil. Vertical growth of roots became prominent after about the 35th day.

Root development in a given volume of soil tend to be "completed" before rapid root growth occurred in soil more distant from the plant; the exception was the development of the brace root sysem.

Only 2 percent of the weight of roots occurred below a depth of 2 feet at maturity.

The weight of roots per acre at maturity was 1,186 pounds.

The shoot-root ratio ranged from 2.2 on the 11th day to 11.1 on the 41st day. This was followed by a decline to a 6.1 and a subsequent increase to 12.8 at maturity. The decline from 11.1 to 6.1 occurred during an eight-day period of rapid brace root development.

DAMPING-OFF OF BLACK PINE, *PINUS NIGRA*, ARN.

By DEMETRIOS S. KAILIDIS[1] *and* FORREST C. STRONG

Department of Botany and Plant Pathology

INTRODUCTION

Damping-off is a universal disease commonly attacking seedlings of conifer and broad leaved trees as well as most herbaceous plants. This disease usually attacks young tender seedlings at soil level, although it may affect the cotyledons and the entire root system.

In the forest tree nursery, the disease is one of the most important causes of losses in the seedling population. Severity of the disease varies from year to year even in the same nursery; in some seasons losses are negligible while in other years heavy losses may occur.

This study concerns several environmental aspects of the damping-off of black pine seedlings and the pathogenic organisms which cause it. The causal organisms were identified from two Michigan nurseries. The relative pathogenicity, frequency and interrelationships of these organisms, were studied. Extensive studies were also made on pure cultures of these pathogenic fungi in various environments, and on the germination of black pine seed under different disease and environmental conditions, in order to obtain a better understanding of the disease process.

MATERIALS AND METHODS

Plantings and Soils

A number of flats containing naturally infested soil from the Bogue Nursery at East Lansing, where conifer seedlings have suffered for many years from damping-off (15), were used in the

[1] Present address: Forest Research Institute, Athens, Greece.

ARTICLE 43–2

greenhouse. These flats were regularly sowed with black pine seed throughout the year. During the summer, sowings were also made in the Bogue Nursery.

Seeds for part of the sowings were surface sterilized with 1:1000 solution of mercuric chloride for 3 minutes and then washed thoroughly with sterile distilled water. Non-sterilized seeds were thoroughly washed with tap water before sowing. The seeds were sowed in flats or in the nursery beds at a depth of 7 to 8 mm., and were covered with the same soil. The number of seeds sowed per row was predetermined from a germination test in sterilized soil in order to insure 100 viable seeds. Watering was adjusted carefully to avoid over or under watering the seedbeds.

The Bogue Nursery soil is sandy and has a pH of 5.5. Changes in the pH of the soil for these studies were made by adding different proportions of 0.1 M phosphoric acid and 0.1 M sodium hydroxide. After such adjustments, the pH was checked for change in 2 or 3 days.

Isolation and Culture of Fungi

Damped-off seedlings were collected once or twice a week for isolation of the causal organisms. The seedlings were washed thoroughly with tap water, surface sterilized with 70 percent alcohol or 1:1000 dilution of mercuric chloride for 2 to 3 minutes; and thoroughly rinsed for 1 to 2 minutes in sterile water. Root and stem pieces from the diseased areas were then aseptically planted on a nutrient medium in Petri plates. Potato dextrose agar (Difco) and malt agar acidified with lactic acid to a pH of 5.0 for control of bacteria were the media used.

Infestation of Soil with Fungi

The fungi used to infest soil were grown on a sterilized mixture of moist vermiculite and cornmeal in Petri plates. After suitable growth had developed in the medium, measured amounts were used as inoculum to infest sterilized soil. Soil samples were autoclaved in the pots or in the flats used for the experiments for one to one and a half hours at 15 pounds pressure. After removal from the autoclave, they were allowed to stand for about one week to minimize undesirable sterilization influences on seed germination and growth, or fungus inoculum. The inoculum was then mixed with the soil in the pots or flats, and the seeds sown.

DISCUSSION OF RESULTS

Isolation and Identification of Causal Fungi, Their Importance and Pathogenicity

Isolation Studies

Isolations from damped-off seedlings of black pine were made periodically and totaled several thousand. Table 1 shows the results of a series of such isolations from both field and greenhouse. The main genera of pathogenic fungi isolated are listed individually. Miscellaneous fungi, normally considered to be saprophytes, include *Mucor, Aspergillus, Penicillium, Alternaria, Botrytis, Rhizopus* and others.

In the greenhouse, when warm, moist conditions prevailed, *Pythium* was the most prevalent cause of damping-off, followed by *Fusarium* and *Rhizoctonia.*

Fusarium was more prevalent and dominated all other genera over a wider range of environmental conditions. Under the cooler, less humid environment of spring and autumn, and under warmer and drier conditions of summer, *Fusaria* were the most prevalent species causing damping-off with *Rhizoctonia solani,* second and *Pythium* third in importance. These results are partially explained by the temperature effects on growth rates of the pathogens (Table 3). The relative importance of *Fusarium* pathogens in these studies is in contrast to the findings of Roth and Riker (12, 13) who reported that *Pythium irregulare* and *Rhizoctonia solani* were the main cause of damping-off on red pine (*Pinus-resinosa*) in Wisconsin nurseries.

Identification, Frequency, and Pathogenicity of Damping-off Fungi

The Genus Pythium

P. irregulare Buisman, *P. debaryanum* Hesse, and *P. ultimum* Trow, were isolated from both damped-off seedlings and from soil in nursery beds and greenhouse flats throughout the year. *P. irregulare* was found to be the most common and the most highly pathogenic. *P. ultimum* was second most prevalent, and *P. debaryanum* was third. Pathogenicity of these species was proved by many reisolations from black pine seedlings grown in sterilized soil which had been infested with these fungi. (Table 2).

TABLE 1—Severity of black pine damping-off and the organisms isolated from damped-off seedlings during the year in the greenhouse and field

Months	Greenhouse field	Days to emergence	Days to highest post emergence D.O.	Days to seedling resistance	Preem. D.O. percent	Postem. D.O. percent	Healthy percent	Organisms isolated from diseased seedlings				
								Pythium percent	*Fusarium* percent	*Rhizoctonia solani* percent	Bacteria percent	Misc. fungi percent
Jan.-Feb.	Greenhouse	8	17	33	58	28	14	45	18	14	12	11
March	Greenhouse	10	21	35	24	64	12	65	14	8	6	7
April	Greenhouse	10	21	35	30	62	8	7	68	18	7	..
May	Greenhouse	10	21	35	28	76	6	8	60	24	..	8
June	Greenhouse	8	17	33	54	38	8	..	80	8	7	5
June	Field	10	21	35	28	30	42	..	91	3	4	2
July-Aug.	Greenhouse	8	17	33	60	32	8	8	60	32	..	..
July-Aug.	Field	10	21	35	39	33	28	..	57	33	..	6
September	Greenhouse	8	17	33	62	27	11	..	62	21	12	5
October	Greenhouse	10	21	35	28	58	14	39	34	..	4	16
November	Greenhouse	8	17	33	59	32	9	15	38	22	11	14
December	Greenhouse	8	17	33	63	19	18	39	19	13	16	13

The Genus Fusarium

The following species were identified from the two nurseries, Bogue and Chittenden: *F. oxysporum* (Schl.) Snyder and Hansen, was most frequently isolated followed by *F. solani* (Mart.) Snyder and Hansen, and *F. Moniliforme* (Sheld.) Snyder and Hansen. All these species cause both damping-off and root rot symptoms. *F. solani* strain 25 and *F. moniliforme* strain 24 produced the greatest amount of damping-off in the comparative trial (Table 2).

TABLE 2—Relative pathogenicity of strains and species of fungus isolates on black pine seedlings in artificially infested soil

Species	Damping-off			Healthy seedlings percent
	Preem. percent	Postem. percent	Total percent	
Pythium irregulare	83	11	94	6
Pythium ultimum	59	26	85	15
Pythium debaryanum	49	33	82	18
Rhizoctonia solani strain 1	55	40	95	5
Rhizoctonia solani strain 4	85	13	98	2
Rhizoctonia solani strain 87	70	18	88	12
Fusarium solani strain 3	49	39	88	12
Fusarium solani strain 25	85	10	95	5
Fusarium solani strain 19	68	6	74	26
Fusarium oxysporum strain 15	74	11	85	15
Fusarium moniliforme strain 24	76	16	92	8

The Genus Rhizoctonia

Many isolations of *Rhizoctonia solani* Kühn were made. Three distinct strains of this fungus were established on the basis of pathogenicity, cultural appearance, growth and behavior. (Tables 2, 3, & 4). *R. solani* strain No. 1, isolated from damped-off seedlings, was highly pathogenic. *R. solani* strain No. 4, isolated from damped-off seedlings, was also highly pathognic, although differing from No. 1 culturally. *R. solani* strain No. 87, isolated from root-rot seedlings, was less pathogenic than strains 1 and 4.

Effects of Environment on Damping-off Fungi

The behavior of damping-off fungi in different artificial environmental conditions is important because it explains, in part, their differences in frequency and pathogenicity in natural environments.

TABLE 3—Growth of fungus isolates at different temperatures, in the dark, on potato dextrose agar at pH 5.5

Isolate	Temperature °C	Average daily radial growth in mm.											
		1	2	3	4	5	6	7	8	9	10	11	12
Pythium debaryanum	12	0	3	9	15	21	27	35	42	..	..	..	..
	16	5	16	33	45	..	..	..	..	..	..	..	..
	20	14	32	45+	..	..	..	..	..	..	..	..	..
	24	20	45	..	..	..	..	..	..	..	..	..	..
	30	20	44	..	..	..	..	..	..	..	..	..	..
	37	0	0	0	0	0	0	..	..	..	..	..	..
Pythium irregulare	12	0	0	5	14	21	27	36	45	..	..	..	..
	16	0	0	17	31	45	..	..	..	..	..	..	..
	20	8	16	41	..	..	..	..	..	..	..	..	..
	24	17	45	..	..	..	..	..	..	..	..	..	..
	30	15	30	45	..	..	..	..	..	..	..	..	..
	37	0	0	0	0	0	0	..	..	..	..	..	..
Rhizoctonia solani No. 1	12	0	0	0	1	1	2	3	5	6	7	10	12
	16	6	12	18	25	31	37	45	..	..	..	..	..
	20	13	28	45	..	..	..	..	..	..	..	..	..
	24	13	34	45+	..	..	..	..	..	..	..	..	..
	30	15	37	45+	..	..	..	..	..	..	..	..	..
	37	15	33	43	..	..	..	..	..	..	..	..	..
Rhizoctonia solani No. 4	12	0	0	0	0	0	0	1	2	3	4	5	7
	16	4	17	24	29	34	41	..	..	..	..	..	..
	20	13	28	45	..	..	..	..	..	..	..	..	..
	24	11	30	44	..	..	..	..	..	..	..	..	..
	30	11	24	35	45	..	..	..	..	..	..	..	..
	37	0	1	2	2	3	3	4	4	5	6	7	8
Rhizoctonia solani No. 87	12	0	1	10	20	31	43	..	..	..	..	..	..
	16	3	21	44	..	..	..	..	..	..	..	..	..
	20	13	37	45	..	..	..	..	..	..	..	..	..
	24	14	45	..	..	..	..	..	..	..	..	..	..
	30	23	45+	..	..	..	..	..	..	..	..	..	..
	37	0	0	0	0	0	0	0	0	0	0	..	..
Fusarium solani No. 25	12	0	0	1	2	3	4	6	7	10	11	12	13
	16	1	3	10	13	16	20	24	28	30	33	36	40
	20	4	11	17	25	32	40	45+	..	..	..	..	..
	24	6	13	20	28	36	44	..	..	..	..	..	..
	30	3	9	14	23	28	35	43	..	..	..	..	..
	37	0	0	0	1	1	1	1	1	..	..	..	..
Fusarium moniliforme No. 24	12	0	1	2	3	4	6	7	9	11	13	15	18
	16	2	4	8	12	15	18	22	26	..	..	..	..
	20	4	11	17	25	32	40	45+	..	..	..	..	..
	24	4	11	18	26	34	42	45+	..	..	..	..	..
	30	10	14	20	26	34	39	45	..	..	..	..	..
	37	0	1	2	3	4	4	5	5	6	6	7	..
Fusarium oxysporum No. 15	12	0	0	1	2	4	5	7	9	10	11	13	16
	16	1	4	9	12	15	18	21	25	27	30	33	36
	20	4	11	17	26	31	39	45	..	..	..	..	..
	24	6	13	20	29	36	44	..	..	..	..	..	..
	30	5	11	18	24	30	37	40	..	..	..	..	..
	37	0	1	1	2	2	2	2	..	..	..	..	..

Growth of the various isolates at different pH levels and temperatures is shown in Tables 3 and 4.

Pythium grew satisfactorily from pH 4.5 to 8.0, with pH 5.5 being

the most favorable. *Pythium* also grew better between 20°C, and 30°C. These results are in general agreement with the work of others (7, 12).

Rhizoctonia solani isolates grew faster between 20°C. and 30°C. At 12°C. the three strains grew at different rates, and two of them were slower than *Pythium* at the same temperature. The growth rates of *Rhizoctonia* varied at different pH levels, but best growth generally

TABLE 4—Growth of fungus isolates at different pH levels, on potato dextrose agar at 24°C in the dark

Isolate	pH	Average daily radial growth in mm.						
		1	2	3	4	5	6	7
Pythium debaryanum	4.5	17	26	39	..	..	..	..
	5.5	20	45	45	..	..	..	..
	6.5	12	26	42	..	..	..	..
	8.0	0	0	0	..	..	..	..
Pythium irregulare	4.5	19	44	..	..	..	..	..
	5.5	17	45	..	..	..	..	..
	6.5	15	39	..	..	..	..	..
	8.0	11	26	44	..	..	..	..
Pythium ultimum	4.5	23	45	..	..	..	..	..
	5.5	18	45	..	..	..	..	..
	6.5	13	26	40	..	..	..	..
	8.0	2	8	12	18	..	..	..
Rhizoctonia solani No. 1	4.5	15	35	45+	..	..	..	..
	5.5	13	34	45+	..	..	..	..
	6.5	15	33	45	..	..	..	..
	8.0	8	18	40	..	..	..	..
Rhizoctonia solani No. 4	4.5	8	18	25	31	36	43	..
	5.5	11	30	44	..	..	..	..
	6.5	1	5	18	25	34	45	..
	8.0	0	1	8	15	21	30	..
Rhizoctonia solani No. 87	4.5	23	45	..	..	..	..	..
	5.5	14	45	..	..	..	..	..
	6.5	0	12	26	43	..	..	..
	8.0	0	0	0	0	..	..	..
Fusarium solani No. 3	4.5	6	10	15	22	28	35	41
	5.5	5	10	16	22	28	36	42
	6.5	6	10	17	23	30	37	43
	8.0	4	10	16	21	27	33	39
Fusarium solani No. 25	4.5	8	14	20	28	34	44	..
	5.5	6	13	20	28	36	44	..
	6.5	8	14	23	30	40	45	..
	8.0	6	12	20	27	34	42	..
Fusarium moniliforme No. 24	4.5	7	14	20	27	34	42	..
	5.5	4	10	18	26	34	42	..
	6.5	8	15	23	31	41	45	..
	8.0	4	12	18	26	33	41	..
Fusarium oxysporum No. 15	4.5	5	10	17	26	32	41	..
	5.5	6	13	20	29	36	44	..
	6.5	8	14	22	30	39	45+	..
	8.0	6	12	18	25	32	40	43

occurred in the slightly acid media, this being in agreement with others (6, 8, 12).

The Fusarium isolates grew more slowly than *Pythium* and *Rhizoctonia* and were less differentially responsive to changes of temperature and pH. The fact that *Fusaria* were less influenced by certain changes of their culture environments probably explains why *Fusaria* predominate under a variety of conditions throughout the year. Others (18, 21) have found that *Fusaria* are widely adapted, and generally can cause severe losses in higher temperatures.

Antibioitc Relationships Between Damping Off Fungi

There is considerable literature on the subject of suppression, antibiosis, and parasitism of several pathogenic fungi by saprophytic ones (7, 10, 14, 19, 20). In the present work, tests were undertaken to determine whether antibiosis was exhibited between the pathogenic fungi either among species of the same genus or of different genera. Paired combinations of the fungi were planted in potato dextrose agar at pH 5.5 and incubated at room temperature in the dark. Each combination was replicated 3 times (Table 5).

TABLE 5—Antibiotic Relationships among the Damping-off Fungi

	F. oxysporum	*F. solani* 3	*P. irregulare*	*P. ultimum*	*R. solani* 1	*R. solani* 87
F. oxysporum	....	(*a*)	....	....	(*c*)	....
F. solani 3	(*a*)	....	(*b*)	....	(*a*)	....
F. moniliforme	(*b*)	(*a*)	(*b*)	(*b*)	(*b*)	(*a*)
P. irregulare	....	(*b*)	....	(*b*)	(*c*)	....
P. ultimum	(*c*)	(*b*)	(*b*)	(*b*)	(*a*)	....
P. debaryanum	....	....	(*b*)	(*b*)	(*b*)	....
R. solani 1	(*c*)	(*a*)	(*c*)	(*a*)	....	....

(*a*) Indicates positive antibiosis (clear zone separating fungi).
(*b*) Indicates no antibiosis (fungi mixed).
(*c*) Indicates partial or weak antibiosis.

Antibiosis was exhibited between several combinations in this test. *Fusarium solani* strain 3 showed antibiosis with both *F. oxysporum* and *F. moniliforme* and also with *R. solani* strain 1 but no antibiosis with *P. irregulare*. *R. solani* strain 87 exhibited antibiosis only with *F. moniliforme* while *R. solani* strain 1 was antagonistic to *P. ultimum* and partially so to *P. irregulare*. The three *Pythium* species showed no antibiotic effects within their own genus.

These antagonisms may partly explain why only a single pathogen was usually isolated from each diseased seedling.

Environmental Effects on Black Pine Seed Germination

Moisture

The first and most significant factor in the germination of seed is probably free moisture. Excessive water, however, reduces aeration which is also an essential factor in seed germination. A laboratory experiment was designed to study these relationships in Petri plates. One filter paper was put on the bottom of each plate, and one over the seed. Water in the plates was adjusted to provide a range varying from minimum to excess of that required for normal germination.

All plates were held in the dark at room temperature (about 22°C). Part of the plates were sealed with wide rubber bands in order to prevent evaporation, and retain constant moisture. The treatments were replicated four times and the experiment performed twice. Germination was considered complete when the radicle was at least 2 mm. in length (Table 6).

TABLE 6—Effects of moisture and aeration on germination of black pine seed in the dark at room temperature

Water per plate	Percentage germination in days						Remarks
	7	8	11	13	15	21	
A. 5 cc. not sealed(*a*)	16	28	76	96(*b*)	100	100	Seed and paper enough moisture.
B. 5 cc. sealed	20	40	72	84	92	96	Seed and paper enough moisture better retention than in A.
C. 10 cc. not sealed	20	40	52	84	92	96	Seed covered at least ½ with water.
D. 10 cc. not sealed	20	40	52	92	96	96	Same as C. Excess water was poured off on 11th day.
E. 10 cc. sealed	20	36	40	61	84	92	Seed ½ covered with water.
F. 15 cc. sealed	16	32	36	60	84	92	Seed ¾ covered with water.
G. 25 cc. sealed	8	20	22	40	60	92	Seed completely covered with water.

(*a*) Rubber band Petri dish seal.
(*b*) Filter paper started to dry, 2 cc. more water was added per plate.

There was better germination up to the 8th day in series B, C, D, and E, where moisture was adequate, than in Series A. Excess water that nearly or completely covered the seed (series F, G) reduced early germination. Although enough free moisture is necessary to initiate germination, aeration seemed to be the critical factor after eight days. Series A, with the best aeration, had the best germination of all.

The sudden gain in germination of seeds in Series D after 11 days can be attributed to the improved aeration from draining the excess water. Series C, where the water was not drained, showed less increase in germination.

Differences in germination of black pine seed as influenced by free moisture were most pronounced through the first 13-15 days. At the end of the twenty-first day, it was found, however, that satisfactory germination (92 percent) occurred even if the seed were completely covered with water as in Series G. This germination would be considered satisfactory except for the fact that it required approximately half again as long as with less water (series A). This would be an unfavorable condition in nature since these poorly aerated germinating seeds would be exposed for a longer time to fungus attack.

Germination of the same seed lot in sterile soil tests varied from 78 to 84 percent but in Petri dishes it was 100 percent.

Temperature

An experiment was designed to find the relationship of temperature and germination of black pine seed. Four replicate Petri dishes, each containing 50 seeds, were used per treatment. The water was at optimum rate and the temperatures varied in dark incubators. Part of the treatments consisted of constant temperatures (Table 7, Nos. 1-8) and the remainder (Nos. 9-17) were 14 hours of a higher temperature and 10 hours of a lower temperature. At constant temperatures, the best germination occurred between 16° and 31°C. At the two lowest temperatures (6°C. and 12°C.), the germination only reached 32 percent. There was a significant increase in germination at 16°C (82 percent) and a double optimum at 24° and 31°C. of 94 percent. Optimum germination for red pine has been reported (1, 12) around 24-26°C., and Haasis (2) found two optima at 24° and 36°C. for red pine and two optima at 24° and 40°C for lodgepole pine. At 37°C there was a decrease in germination to 44 percent.

At alternating temperatures, the germination was more or less the same for all combinations of 24, 28, and 31°C. with the lower tempertaures. This indicates that if one temperature was favorable for enough hours per day, the alternate temperature did not seriously affect the percentage of germination. When as high a temperature as 37°C. (known to be unfavorable when constant) was combined with a lower temperature of 6° or 16°C., a favorable germination condition still prevailed although the extreme fluctuation to 6° (84 percent) was lower than the 31-16° combination (92 percent).

TABLE 7—Effects of constant and alternating temperatures on germination of black pine seed in the dark

No.	Temperature	Days					
		7	9	11	14	16	19
1.	6°C (constant)	0	4	12	16	28	32
2.	12°C (constant)	0	4	12	16	28	32
3.	16°C (constant)	0	12	24	40	72	82
4.	20°C (constant)	4	20	32	56	80	84
5.	24°C (constant)	16	36	56	80	92	92
6.	28°C (constant)	12	28	44	60	72	84
7.	31°C (constant)	12	36	56	72	88	92
8.	37°C (constant)	0	16	20	20	40	44
9.	24°C (14 hrs.), 6°C (10 hrs.)	12	20	36	60	84	92
10.	24°C (14 hrs.), 12°C (10 hrs.)	16	32	52	72	92	92
11.	24°C (14 hrs.), 16°C (10 hrs.)	12	28	52	72	94	96
12.	28°C (14 hrs.), 6°C (10 hrs.)	10	18	36	64	84	88
13.	28°C (14 hrs.), 16°C (10 hrs.)	8	16	24	60	84	88
14.	31°C (14 hrs.), 6°C (10 hrs.)	16	24	48	80	88	92
15.	31°C (14 hrs.), 16°C (10 hrs.)	14	20	40	80	96	96
16.	37°C (14 hrs.), 6°C (10 hrs.)	34	46	60	80	84	84
17.	37°C (14 hrs.), 16°C (10 hrs.)	40	52	68	92	92	92

Acidity of the soil

A soil test was used to determine the influence of pH on the germination of black pine seeds in the greenhouse. The soil used, designated herein as Type F (c.f. Table 11), contained 3.3 percent humus, sand 86.00 percent, silt 4.00 percent, and clay 6.7 percent. The soil was buffered to the desired pH with 0.1 M phosphoric acid and 0.1 M sodium hydroxide and sterilized. Four replicate pots, each sown with 50 seeds, were used for each pH value.

Soil acidity was found to influence seed germination (Table 8)

TABLE 8—Relative germination speed and total germination of black pine seed at different pH levels in sterile soil

pH	Total number of seed germinated, percentage in days									
	12	14	16	19(*a*)	21	23	26	28	31	33(*a*)
4.5	11	15	31	50	56	68	72	74	74	78
7.0	..	5	17	32	42	48	50	56	56	56
8.5	..	..	4	8	23	29	32	32	32	32

(*a*) Time seedling root and stem measurements were taken (data in Table 9).

both as to earliness and total emergence. At a pH of 7.0, germination was delayed two days after that at pH 4.5 and there was another two-day delay at pH 8.5. Total emergence at pH 8.5 was less than half that at pH 4.5 (32 and 78 percent).

The results of root and stem measurements of representative seedlings grown at the different pH levels is given in Table 9. Ten seedlings were collected at random from each of four pots 19 and 33 days after sowing. The nineteenth day was usually the time of highest post emergence damping-off, and the thirty-third was the time when the seedlings had passed their susceptible state (Table 1).

At 19 days, the roots were longest at pH 4.5, shorter at pH 7.0, and shortest at pH 8.5. Thus, at the time of highest damping-off and fungus activity, the differences in root length were most striking for the various pH levels. Differences were similar but smaller at 33 days. Stem lengths also differed somewhat at different pH levels on the 19th day. On the 33rd day, they were the same at pH 7.0 as at pH 8.5 and only slightly longer at the optimum level of pH 4.5.

TABLE 9—Root and stem length of black pine seedlings at different pH values in sterile soil

pH	19 days after sown			33 days after sown		
	Root cm.(*a*)	Stem cm.(*a*)	Total length cm.	Root cm.(*a*)	Stem cm.(*a*)	Total length cm.
4.5	5.45	3.25	8.70	6.50	3.45	9.95
7.0	3.90	2.60	6.50	5.80	3.20	9.00
8.5	3.30	2.50	5.80	5.00	3.20	8.20

(*a*) Average of 10 representative seedlings per replication.

These results are in accord with those of other investigators working with various conifer species. Jackson (4) found the total length of Douglas fir was greater at pH 3.5 to 5.5, and the total length of Ponderosa pine was greater at pH 4.5. Roth and Riker (12) found that the optimum range for root growth of red pine in soil extended from about pH 4.7 to 6.0.

The Relationships Between Damping-Off of Black Pine and Environment

Temperature

Total damping-off (pre- and postemergence combined) was found to be high all the year around under various greenhouse conditions, this being in agreement with others (77, 79). Pre-emergence damping-off was higher during the winter months, when the greenhouse was heated, (Table 1) and during the summer months, when the greenhouse could not be cooled. Post-emergence damping-off, on the other hand, was higher during the cooler periods of spring and autumn.

Seedling emergence was shown to begin in eight days during the warmer periods and in 10 days under cooler conditions (Table 1). The highest percentage of post-emergence damping-off occured at 17 days under higher temperature conditions and at 21 days in cooler periods. Black pine seedlings became resistant to damping-off in 33 days at higher temperatures and in 35 days in cooler periods.

Pre-emergence damping-off of black pine seedlings was more severe at the warmer temperatures (Table 1) because the pathogenic fungi isolated also grew better at higher temperatures, i.e. between 20° and 30°C (Table 3). It has been demonstrated that the severity of pre-emergence damping-off is determined to a considerable degree by the relative growth rates of host and pathogen and is most severe at temperatures that are relatively less favorable to the host than the pathogens as measured by the ratio of their growth rates (5).

Soil acidity

It has been known for many years that acid soils reduced conifer damping-off losses, while in alkaline soils, the losses were heavy (3, 4, 12, 17). In the present work, it was found that the pathogenic damping-off fungi really thrive in acid environment and grow less vigorously in alkaline conditions (Table 4). It also was found that black pine seeds germinated faster and better in acid soils and the seedlings grew better (Tables 8 and 9). The net effect then was less

damping-off, even though the environment was favorable to the fungi. The importance of the environmental factors was studied in relation to the pathogenic process itself.

One eighth of a plate of cornmeal-vermiculite inoculum of *Fusarium moniliforme* or *Rhizoctonia solani* inoculum was mixed into each pot of soil. Fifty surface sterilized black pine seeds were sowed in each 4-inch pot of sterilized, pH adjusted soil. Four pots were used for each pH value and fungus. Watering was as usual. The experiment was repeated twice.

At pH 4.5, the pre-emergence and total damping-off were less than at pH 7.0 and pH 8.5 with both fungi tested, although *F. moniliforme* was less pathogenic than *R. solani* (Table 10).

It was evident that less damping-off occurred in acid soils, not only because seedlings grow better, but because seeds also germinated better, earlier, and faster than in alkaline soils. Thus, seedlings had a better chance to escape damping-off and reach maturity sooner.

Soil Composition

In order to find what relationships exist between soil quality and damping-off, soil of different types was used (Table 11). All soils were sterilized and equalized at pH 6.0 with buffers and inoculum was of the cornmeal vermiculite type. Two kinds of inoculations were made: heavy (Table 11) in which one third of a Petri dish culture was added per 4-inch pot, and light inoculum in which one eighth of a culture was used per pot. Eight pots were used for each soil type and pathogen. Fifty seeds were sowed per pot. Watering was as usual.

Damping-off was more severe for *Fusairum solani* strain 25 under heavy inoculation (Table 11) than with a light inoculation.

In pure sand, four of the five isolates caused less damping-off than in sands which contained a fungus nutrient or peat. In other soils, most disease occured in muck which contained 46.6 percent humus. Soils D, E, and F with various percentages of humus, sand, silt, and clay (c.f. Table 11) had less damping-off. It was lowest in series F containing 3.3 percent humus.

Rhizoctonia solani strain 4 caused heavy losses in all types of soil (Table 11). *Pythium irregulare* gave heavier losses in muck soil and in sand containing peat or nutrient solution, and less with D, E, and F soil types. Even in the latter soils, however, the losses must be considered heavy. In nature *Pythium* spp. are predominant in

TABLE 10—Effect of pH of soil on damping-off of black pine seedlings.

pH	Organism	Germination days	Percentage postemergence damping-off in days						Damping-off			Alive
			17	20	21	23	25	28	Preem.	Postem.	Total	Total
4.5	*F. moniliforme*	11	..	3	2	3	10	3	32	21	53	47
7.0	*F. moniliforme*	13	..	..	13	..	1	..	71	14	85	15
8.5	*F. moniliforme*	15	4	..	..	..	..	..	96	4	100	0
4.5	*R. solani No. 4*	11	4	3	4	2	2	..	65	15	80	20
7.0	*R. solani No. 4*	..	..	..	..	..	..	..	100	..	100	0
8.5	*R. solani No. 4*	..	..	..	..	..	..	..	100	..	100	0

TABLE 11—Effect of soil composition on damping-off caused by fungus isolates with two rates of inoculum at pH 6.0 in the greenhouse

Soil	Soil content				*P. irregulare*(a) damping-off			*R. solani*(a) damping-off			*F. oxysporum*(a) #23 damping-off			*F. moniliforme*(a) #24 damping-off			*F. solani*(a) #25 damping-off			*F. solani*(b) #25 damping-off		
	Humus pct.	Sand pct.	Silt pct.	Clay pct.	Preemerg. D.O. pct.	Post emerg. D.O. pct.	Healthy pct.	Preemerg. D.O. pct.	Post emerg. D.O. pct.	Healthy pct.	Preemerg. D.O. pct.	Post emerg. D.O. pct.	Healthy pct.	Preemerg. D.O. pct.	Post emerg. D.O. pct.	Healthy pct.	Preemerg. D.O. pct.	Post emerg. D.O. pct.	Healthy pct.	Preemerg. D.O. pct.	Post emerg. D.O. pct.	Healthy pct.
Sand	0	100	0	0	88	6	6	100	0	0	82	12	6	79	24	7	66	22	22	35	37	28
Sand+nutrient(c)	0	100	0	0	96	4	0	100	0	0	100	0	0	88	12	0	82	12	6	...	...	...
Sand+peat	10	90	0	0	100	0	0	100	0	0	100	0	0	94	6	0	73	17	6	...	...	...
Soil D	2.0	89	3.0	6.0	84	12	4	100	0	0	47	35	18	68	16	16	45	41	14	46	12	42
Soil E	2.6	89.4	2.0	6.0	85	8	7	96	4	0	56	24	20	70	12	18	66	12	22	...	...	...
Soil F	3.3	86	4.0	6.7	84	8	8	100	0	0	45	25	30	44	20	36	56	12	28	20	22	58
Muck	46.6	...	...	...	94	6	0	100	0	0	60	40	0	88	12	0	100	0	0	28	40	32
Clay	1.3	70.7	9.0	19.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	78	19	2

(a) Heavy inoculum.
(b) Light inoculum.
(c) Sand watered with a fungus nutrient solution.

soils with high humus content (3, 11). With *Fusaria*, again there were heavy losses on muck soil and sand plus peat or nutrient solution, and less disease with soil type F.

The length and weight of green and dry seedlings were obtained in this test. Thirty-three seedlings, 16 days old, were collected at random from pots of each soil type. The average dry weight per centimeter of seedling length was calculated, since the length of seedlings varied with the soil type. There was no correlation between dry weight per centimeter and severity of damping-off. Root length and total length of black pine seedlings were greater in sand alone than in muck soil. Stems were shorter than roots in all the soils tested, but in the case of muck soil the root-stem ratio was smallest.

These data indicate that soil type is an important factor in the amount and severity of damping-off. Along with other environmental conditions, soil type influences both fungus growth and growth and vigor of the host.

SUMMARY

The causal agents of damping-off of black pine in Michigan forest nursery soils proved to be, in order of their prevalence, *Fusarium oxysporum, F. solani, F. moniliforme, Rhizoctonia solani, Pythium irregulare, P. ultimum and P. debaryanum.*

Rhizoctonia solani was the most pathogenic species, with *Fusarium solani* second and *Pythium irregulare* third, followed by *F. moniliforme* and *F. oxysporum*. *P. ultimum* was about equal in pathogenicity with *F. oxysporum* and *P. debaryanum* was slightly less pathogenic.

In culture studies, *Pythium* generally grew better at pH 5.5 and in temperatures between 20° and 30°C. *Rhizoctonia* grew faster between 20° and 30°., and at the lowest temperature tested (12°C) was slower than *Pythium*. *Rhizoctonia* grew well at pH 4.5, 5.5 and 6.5, and its growth at pH 8.0 was satisfactory. *Fusarium* was adapted to a wider range of environmental conditions than the other genera. *Fusarium* grew slower than *Pythium* and *Rhizoctonia*, but the difference among the species and strains tested in various environments were less than those of the other two genera.

When the pathogenic fungi were grown together by pairs on potato dextrose agar, antibiosis was observed in some cases. *Fusarium solani* strain 3 exhibited antibiosis with *F. oxysporium* and *F. moniliforme*

as well as with *Rhizoctonia solani*. *R. solani* strain 1 was antagonistic to *Pythium ultimum* and partially so to *P. irregulare*. The three *Pythium* specis showed no antibiotic effects among their own genus.

Studies on black pine seed germination showed that moisture is necessary for initiation of seed germination. After a few days, aeration became the critical factor, and total germination was best at the lowest moisture content tested. At constant temperature, black pine seed germination showed two optima at 24° and 31°C. Alternating temperatures resulted in the same germination if one temperature of the combination was favorable or optimum. But if alternative temperatures were neither one favorable, this condition stimulated germination above that at either temperature when constant.

As to the relation of black pine seed germination and pH of the soil, it was found that at pH 4.5 total germination number was approximately twice that at pH 8.5, and it occurred in much less time. This is correlated to the occurrence of damping-off, since rapidly germinating seed and fast growing seedlings reach their resistant stage sooner and can escape damping-off. Black pine seedlings reach maturity 25 to 27 days after emergence. At pH 4.5, the pre-emergence and total damping-off were less than at pH 7.0 and pH 8.5 in soil infested with pure cultures of *Fusarium* and *Rhizoctonia*.

Soil type and fertility also influence occurrence of damping-off of black pine seedlings. Losses were less in a soil of medium fertility than in either sand or muck soil.

LITERATURE CITED

1. Baldwin, H. I. (1934). Germination of red spruce. Plant Physiol. 9: 491-532.
2. Haasis, F.W. (1928). Germinative energy of lots of coniferous-tree seed, as related to incubation temperature and to duration of incubation. Plant Phys. 3: 365-412.
3. Hartley, C. (1921). Damping-off in forest nurseries. U.S. Dept. Agr. Bul. No. 934. pp. 99.
4. Jackson, L.R. (1940). Effects of H-ion and Al-ion concentrations on damping-off of conifers and certain causative fungi. Phytopath. *30*: 563-578.
5. Leach, L.D. (1947). Growth rates of host and pathogen as factors determining the severity of pre-emergence damping off. Jour. Agr. Res. *75*: 161-179
6. LeClerg, E. L. (1934). Parasitism of *Rhizoctonia solani* on sugar beet. Jour. Agr. Res. *49*: 407-431.

7. Luke, H.H., and T.D. Connel (1954). Studies on antibiotic soil organisms. II. Bacteria and fungi antagonistic to *Pythium arrhenomanes* in sugar cane soils in Louisiana. Phytopath. *44*: 377-379.
8. Matsumoto, T. (1921). Studies in the physiology of the fungi. XII. Physiological specialization in *Rhizoctonia solani* Kühn. Mo. Bot. Gard. Ann. *8*: 1-62.
9. Middleton, J.T. (1943). The taxonomy, host range and geographic distribution of the genus *Pythium*. Memiors of the Torrey Bot. Club. *20*: 1, pp. 171.
10. Ram, C.S.V. (1953). Sensitivity of *Fusarium vasinfectum* to antagonistic micro-organisms in the soil. (Abstr.) Phytopath. *43*: 482.
11. Roth, L.F., and A.J. Riker (1943). Life history and distribution of *Pythium* and *Rhizoctonia* in relation to damping-off of red pine seedlings. Jour. Agr. Res. *67*: 129-148.
12. ....., and A. J. Riker (1943). Influence of temperature, moisture, and soil reaction on the damping-off of red pine seedlings, by *Pythium* and *Rhizoctonia*. Jour. Agr. Res. *67*: 273-293.
13. ....., and A.J. Riker (1943). Seasonal developement in the nursery damping-off of red pine seedlings caused by *Pythium* and *Rhizoctonia*. Jour. Agr. Res. *67*: 417-431.
14. Sanford, G.B. (1939). Research on certain soil-borne diseases as affected by other micro-organisms. Sci. Agr. *19*: 609-615.
15. Strong, F. C. (1952). Damping-off in the forest tree nursery and its control. Mich. Agr. Expt. Sta. Quart. Bul. *34*: 285-296.
16. Tint, H. (1945). Studies in the *Fusarium* damping-off of conifers. I. The comparative virulence of certain *Fusaria*. Phytopath. *35*: 421-439.
17. ....., (1945). Studies in the *Fusarium* damping-off of confiers. II. Relation of age of host, pH, and some nutritional factors to the pathogenicity of *Fusarium*. Phytopath. *35*: 440-457.
18. ....., (1945). Studies in the *Fusarium* damping-off of conifers. III. Relation of temperature and sunlight to the pathogenicity of *Fusarium*. Phytopath. *35*: 498-510.
19. Weindling, R. (1934). Various fungi recently found to be parasitic on *Rhizoctonia solani* (Abstr.) Phytopath *24*: 1141.
20. ....., (1934). Studies on a lethal principal effective in the parasitic action of *Trichoderma lignorum* on *Rhizoctonia solani* and other soil fungi. Phytopath. *24*: 1153-1179.
21. Wollenweber, H.W., and O.A. Reinking. Die Fusarien. Paul Parey, Berlin.

GERMINATION OF PEA BEANS AS AFFECTED BY MOISTURE AND TEMPERATURE AT IMPACT LOADING[1]

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The limited research work investigating the physical damage to beans has been essentially from the standpoint of seed producers and growers. An investigation by the Associated Seed Growers, Inc. (1949), indicated that the percent of live seed was reduced when Tendergreen bean seeds were dropped from 6 inches to 6 feet onto a heavy aluminum plate. As height of drop and number of times dropped increased, and as moisture decreased, a reduction in live seed was observed. Certain handling operations were also shown to reduce live seed.

In studying thresher injury as a cause of baldhead in field and snap-beans, Harter (1930) observed differences in the source of test lots which he associated with the condition of the pods when threshed and as influencing baldhead. Borthwick (1932) found that detachment of the cotyledons was one of the most common injuries and that seedling growth of Lima beans was retarded as one or both cotyledons were missing. Tests indicated that machine threshing was responsible for such injury found in bean seedlings. There has been a growing awareness in the bean industry that handling operations during processing cause objectionable damage to pea beans.

Experimental work was conducted by Perry (1959) to observe the effect of moisture and temperature on damage to pea beans when dropped in a manner simulating actual handling practices.

PROCEDURE

Carefully harvested pea beans of excellent quality, and essentially free of all visible damage, were selected for the study. Portions of

[1] Acknowledgement is given to M. S. Sefcovic, Food Technologist, A.M.S., U.S.D.A., for his advice and consultation during the course of this investigation.

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these beans were slowly dried to 12 percent, 14 percent, 16 percent, and 18 percent moisture content and held for moisture to equalize. Samples at these various moisture contents, consisting of groups of 600 individual beans were dropped from a height of 22½ feet through a 4-inch vertical tube onto other pea beans of about 18 percent moisture content. The temperature of the experimental bean samples dropped, as well as the beans on which the samples landed, were maintained at either 40° F. or 55° F.

After dropping, the experimental beans were carefully inspected and all broken beans and beans with cracked seed coats removed. The remaining beans that had no visible evidence of damage, together with beans from the original portions that had been dried to the various experimental moisture contents but not dropped, were used in sand germination tests to establish the extent of internal damage.

Germination flats were partially filled with properly dampened fresh No. 1 plastering sand. One hundred beans were positioned at ¾-inch intervals and covered with a 1-inch layer of sand. The prepared flats were placed in a germinator and water maintained in the bottom to insure a high humidity. Temperature in the germinator varied from about 65° F. at night to 75° F. to 80° F. during the day. The germination tests were repeated to utilize 400 beans from each lot. Interpretations of the tests were made seven days after planting according to a classification based on recommendations in the Agricultural Handbook No. 30, Testing Agricultural and Vegetable Seeds.

PRESENTATION OF DATA AND DISCUSSION

The percentages of visibly damaged beans removed from the samples before making germination tests are listed in Table 1. This damage was essentially cracked seed coats. Increased damage is

TABLE 1—Percentages of pea beans having visible damage after a 22½-foot experimental drop

Moisture (%).....	12		14		16		18	
Temperature (°F)....	40	50	40	50	40	50	40	50
Visible damage (%)..	7.0	6.7	1.8	1.2	1.0	1.0	0.2	0.2

apparent at lower moisture contents. There is slight evidence of increased damage at lower temperatures.

The results of the germination tests are presented in Table 2. Each percent given represents the average of the four replications of 100 beans each. A statistical analysis, made on the basis of the percent normal seedlings in each replication, indicated significant differences between all treatment and moisture averages except for 16 percent and 18 percent moisture.

The "normal" plants (seedlings) were divided into several classifications so that the number of seedlings with no defects could be determined. Imperfectly formed seedlings, though they would produce normal plants under favorable conditions, are handicapped in competing with other plants under field conditions. In a discussion of thresher injury to baby Lima beans, Borthwick (1932) states that detachment of the cotyledons is one of the most common injuries. He points out that either one or both may be missing and that the seedlings are retarded, although the retardation is much more pronounced in the latter than in the former case.

The percentages of decrease in germination (normal seedlings) for the four moisture and two temperature levels are presented in Fig. 1 and the percentages of decreased in normal seedlings with no defects are presented in Fig. 2. A greater reduction in germination and normal plants with no defects is evident at 40° F. than at 55° F. Also, a marked reduction in germination, and plants with no defects is apparent in 12 percent moisture beans.

The detrimental effect of dropping pea beans of good quality is clearly evident. Under field conditions, only a portion of the normal seedlings with defects will be able to produce strong plants under field conditions. Thus, the percentage decrease in strong productive plants under field conditions would be between the values found in Fig. 1 and 2. It is also probable that a low percentage of the beans showing visible damage would produce strong plants under field conditions. However, this would represent only a small change in the data presented, had it been included.

A difference due to moisture but no appreciable difference due to temperature is indicated on the basis of the visible damage (Table 1). The germination tests (Fig. 1), however, were effective in establishing both a moisture and a temperature difference. This shows germination tests to be more effective in establishing mechanical damage and that

TABLE 2—Germination tests of beans from samples dropped and not dropped experimentally (a)

Treatments	Not dropped				Dropped at 55° F.				Dropped at 40° F.			
Moistures (percent, w.b.)	12	14	16	18	12	14	16	18	12	14	16	18
Normal seedlings												
1. No defects	94.25	88.75	91.50	93.00	59.75	81.50	85.00	89.50	54.75	77.25	82.00	80.25
2. Damaged hypocotyl and "knees"	.....	0.25	1.75	0.50	1.75	1.75	1.00	.....	2.25	0.75	1.50	0.25
3. Primary leaf missing or damaged	0.75	1.50	1.50	0.75	1.50	2.00	2.75	2.00	1.50	2.00	1.75	4.75
4. Cotyledon missing or damaged	1.00	1.00	.....	0.50	11.25	3.25	3.00	1.75	12.00	4.00	2.25	1.00
5. Combinations of 2, 3, or 4	.....	.....	.....	.....	4.25	1.50	0.25	.....	2.25	1.50	1.50	0.75
Total (percent germination)	96.00	91.50	94.75	94.75	78.50	90.00	92.00	93.75	72.75	85.50	89.00	87.00

(a)Table values are percents based on the germination of 400 beans at each moisture and temperature. Height of drop was 22 1/2 feet.

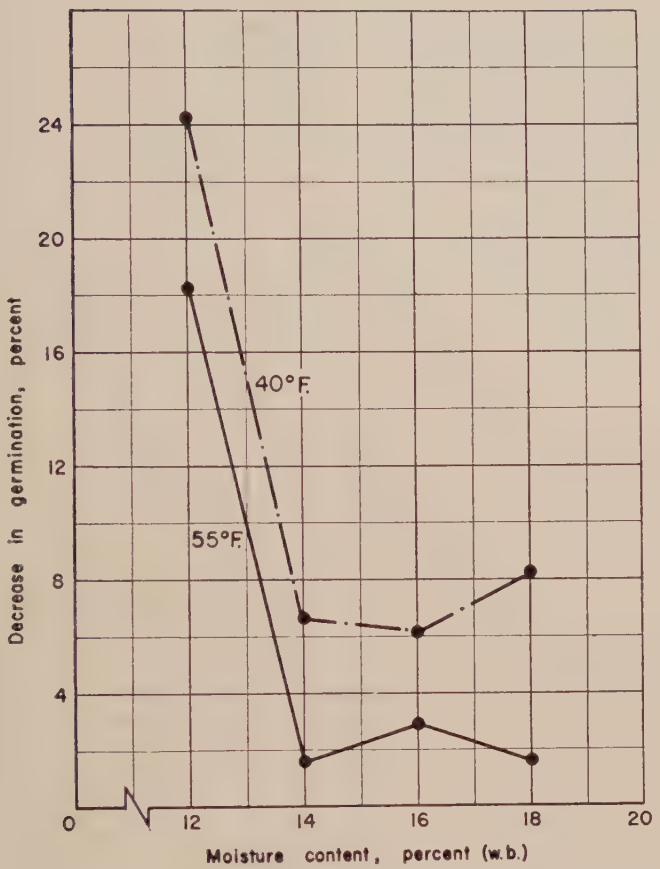

Fig. 1. Percent decrease in germination vs. moisture content (w.b.) for pea beans dropped 22½ feet at 40° F. and 55° F.

temperature and moisture adjustment may be a means of controlling damage to beans that are to be handled.

Additional data would be needed to establish the relationships for different strains and varieties, but the same general trends would be expected. Solorio (1959) found that strains of pea beans differed in visible injury sustained from mechanical beating, and that the study of germination abnormalities was more sensitive in measuring mechanical damage. Koehler (1957) observed that in dropping grains of seed corn, differences between hybrids was as marked as differences due to stage of maturity.

CONCLUSIONS

1. Experimentally dropping selected pea bean samples 22½ feet to establish the effect of moisture and temperature produced 0.2 percent cracked seed coats at 18 percent moisture content beans to 7.0 cracked seed coats at 12 percent moisture beans at 40° F.
2. The decrease in germination in the beans having no visible damage after being experimentally dropped at 55° F. was 2 percent for pea beans of 14 percent, 16 percent, and 18 percent moisture and 18 percent for beans of 12 percent moisture content. At 40° F. these decreases were from 6 percent to 8 percent for pea beans

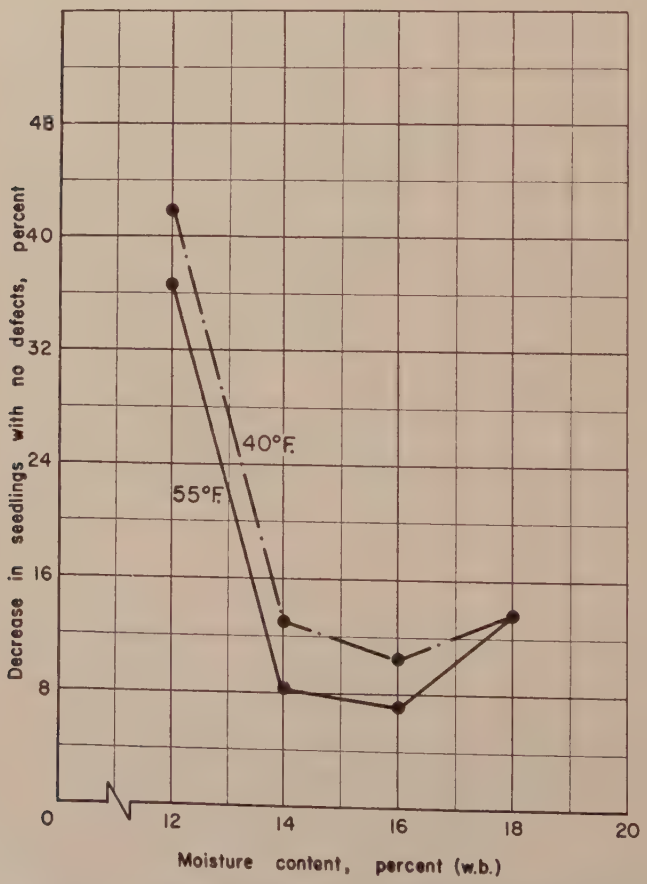

Fig. 2. Percent decrease in seedlings with no defects vs. moisture content (w.b.) for pea beans dropped 22½ feet at 40° F. and 55° F.

of 14 percent, 16 percent, 18 percent moisture and 24 percent for beans of 12 percent moisture.

3. The reduction in normal plants with no defects, which would more closely reflect change in field value, approached twice the decreases observed in germination.
4. Germination tests were effective in establishing both a temperature and moisture effect in the dropping of beans, whereas through visible inspection for damaged seed coats, only a moisture effect could be definitely established.

REFERENCES

Agricultural Handbook No. 30 (1952). Testing agricultural and vegetable seeds. U.S. Government Printing Office, Washington.

Borthwick, H.A. (1932). Thresher injury in baby Lima beans. Jour. Agr. Res. 44:503-510.

Harter, L.L. (1930). Thresher injury a cause of baldhead in beans. Jour. Agr. Res. 40:371-384.

Perry, J.S. (1959). Mechanical damage to pea beans as effected by moisture, temperature, and impact loading. Thesis for degree of Ph.D., Mich. State Univ., East Lansing. (Unpublished)

Koehler, B. (1957). Pericarp injuries in seed corn. Ill. Agr. Expt. Sta. Bul. 617. 72 pp.

Solorio, C. B. (1959). Mechanical injury to pea bean seed treated at three moisture levels. Thesis for the degree of M. S., Mich. State Univ., East Lansing. (Unpublished)

A GYNOECIOUS INBRED LINE OF CUCUMBER

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A NEW CUCUMBER BREEDING LINE, MSU 713-5, has been established and demonstrated to be homozygous for gynoecious sex expression under normal greenhouse and field environments. A typical plant of MSU 713-5 is illustrated in Fig. 1. This inbred line is of interest in the development of commercial F_1 hybrids and of theoretical interest as experimental material for studies on the genetics and physiology of sex expression.

MSU 713-5 was developed by crossing a gynoecious segregate found in the Korean cucumber variety, Shogoin (PI 220860), and the pickling cucumber variety, Wisconsin SMR 18. The latter variety was developed and described by Walker.[1] Four backcrosses were made to Wisconsin SMR 18. In each backcross generation, an extreme female plant was selected and crossed to the recurrent parent. Two generations of inbreeding were then accomplished by selfing predominantly female segregates.

Three additional generations of selfing and one mass increase were accomplished by gibberellin[2] induction of staminate flowers on gynoecious plants following procedures outlined by Peterson and Anhder.[3] This procedure normally requires two or three weekly foliar applications of 1500 ppm gibberellin A_3 beginning when the second true leaf is expanded to 1-inch diameter to provide adequate pollen production for self-pollinations and mass increase.

Several thousand plants of MSU 713-5 have been observed under field conditions in Michigan and Sinaloa, Mexico without discovering any plants bearing staminate flowers.

[1] Walker, J. C. (1958). Two new pickling cucumber varieties resistant to scab and mosaic. *Plant Disease Reporter* 42: 1337-1338.

[2] The gibberellin used was an emulsifiable formulation of potassium gibberellate supplied by Merck and Company, Rahway, New Jersey.

[3] Peterson, C. E. and L. D. Anhder (1960). Induction of staminate flowers on gynoecious cucumbers with gibberellin A_3. *Science* 131: 1673-1674.

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Fig. 1. A typical plant of gynoecious inbred MSU 713-5 with leaves removed showing only pistillate flowers. The line is maintained and increased by means of gibberellin induction of staminate flowers to supply pollen.

MSU 713-5 produces a black spined, pickling-type fruit with a length/width ratio of approximately 2.8:1. The plants are uniform and vigorous, producing two to four strong lateral branches. Pistillate flowers are borne singly at every node on the entire plant with the first functional flowers developing at the second or third node. This inbred shows some tolerance to mosaic and is resistant to scab.[4] Hybrids produced by using MSU 713-5 as the seed parent are undergoing extensive commercial trials in Michigan this year.

Hybrid seed production procedures, as outlined by Peterson and Weigle,[5] involve the removal of all monoecious plants from lines segregating for sex expression, leaving only gynoecious plants to be pollinated by a selected male parent. This operation is similar to the detasseling operation in hybrid corn seed production except that it involves rogueing of monoecious plants instead of emasculation.

[4] Inoculations with cucumber virus 1 and scab (*Claudosporium cucumerinum*) were made by Dr. D. J. deZeeuw of the Department of Botany and Plant Pathology.

[5] Peterson, C. E. and J. L. Weigle (1958). A new method of producing hybrid cucumber seed. Mich. Agr. Expt. Sta. Quart. Bul. 40: 960-965.

In hybrid seed production, using MSU 713-5 and other gynoecious lines, the rogueing operation for removal of monoecious plants in female rows is eliminated.

Limited studies of staminate flower production on hybrids produced with MSU 713-5 were made in the greenhouse in 1959. On 29 plants of the gynoecious x monoecious F_1 hybrid, MSU 713-5 x MSU 238, the staminate:pistillate flower ratio was approximately 1:1 up to node six. From that stage on, fewer and fewer staminate flowers were produced until about node 16, after which no more staminate flowers were produced on any of the plants.

Total flower production on the 29 plants was 133 staminate and 261 pistillate up to the 16th node. From these observations, it seems likely that such hybrids will not produce sufficient pollen for fruit production in commercial fields, and it may be necessary to provide a supplemental source of pollen by blending seed of monoecious varieties or providing pollen rows in commercial fields.

By utilizing the methods followed in producing MSU 713-5, it is possible to develop homozygous gynoecious lines and gynoecious F_1 hybrids of any type of cucumber. Gynoecious F_1 hybrids were produced under screen isolation cages in 1959 by staminate flower induction on one of two gynoecious parent inbred lines. Gynoecious sex expression may be introduced into certain European greenhouse varieties, which set fruit parthenocarpically, to eliminate the problem of unwanted pollinations in greenhouse cucumber production.

The early development of pistillate flowers, concentrated fruit production, and higher yields are important advantages gained through the use of F_1 hybrids. Gynoecious sex expression from MSU 713-5 can be readily incorporated into other parent lines. Since the procedures involved in utilizing gynoecious cucumber plants for commercial production of hybrid seed are simple and inexpensive, it is expected that hybrid varieties of cucumber will become as universally accepted as those of corn and other hybrid crops.

FRUIT SET OF EMASCULATED AND HAND-POLLINATED PEACH AND APRICOT BLOSSOMS IN DIFFERENT MICRO-ENVIRONMENTS

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INTRODUCTION

FOR MANY YEARS, peach and apricot breeding at Michigan State University's South Haven Experiment Station has been seriously hampered by weather. It is frequently wet, cold, windy, and in general quite unfavorable for obtaining an adequate set of fruit from emasculated and hand-pollinated blossoms. In some years, 40 to 50 percent of the emasculated and hand-pollinated blossoms set fruit. However, this is higher than average, and a 10 percent fruit set is more typical. Sometimes no fruit at all is obtained.

In a given year, the period during which flowers are at the proper stage for emasculation and artificial cross-pollination is usually only about one or two days. Thus, it is usually impossible to repeat a series of crosses in a given year if for any reason they are not successful.

Failure to obtain fruit may result in the loss of invaluable breeding material and new varieties of economic importance, as well as a year's time in procuring the desired crosses. It is important to take every precaution to avoid these serious losses.

In some areas, entire plants have been covered for protection against weather. In more severe climates, trees are sometimes moved into the greenhouse where the crosses are made. Since neither of these systems seemed practical in Michigan, the possibility of covering branches with various types of protectors to provide a micro-environment favorable for fruit set was investigated.

In breeding many crops, entire plants or plant parts are often covered, following the hand-pollination of flowers, to protect them

[1] Now in the Department of Horticulture, Washington State University, Pullman, Washington.

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from contamination with foreign pollen. Manipulation of the micro-environment in the field by bagging or by using tents has also been used to study fruitfulness in tree fruits, but no reference was found in the literature relating to the control of the micro-environment about branches of fruit trees to improve the set of fruit from emasculated and hand-pollinated blossoms.

MATERIALS AND METHODS

The experiments described below were conducted at the Merkle and Station farms of the South Haven Experiment Station, and they will be referred to in that manner throughout the text.

Pollen Collection

About 3 to 4 days before apricot and peach trees were expected to bloom in the field, branches of Kalhaven peach, Curtis apricot (seedling name), and SHA#6 (South Haven Apricot #6) were brought inside for bud forcing and pollen collection. To make sure the pollen was viable, germination tests in sucrose solution were made.

Apricot Experiments

On April 24, 1957, pollinations were made at the Merkle farm using Curtis as the pollen parent and Perfection as the seed parent. Branches which were comparable in all ways possible, well distributed over the tree, of a suitable size for bagging, in good condition, and which had a sufficient number of blossoms were selected for the treatments and controls. Side branches, which were too long to fit properly under the protectors, were headed back. The protectors were 2′ x 4′ and made from three types of material—3 mil clear polyethylene, waxed white parchment, and unwaxed white parchment (Fig. 1).

Only blossoms which were in an expanded balloon stage, but not yet open at the tips, were selected for emasculation and pollination. All other blossoms were removed from the branches. Counts were made of all pollinated pistils on each branch, a thermocouple was secured in a central position on the branch, and the branch was covered with a protector which was tied securely.

Control branches were not bagged but were otherwise handled the same as the treated branches. Each type of protector was con-

Fig. 1. Polyethylene, waxed parchment, and unwaxed parchment protectors on Redhaven peach trees.

sidered as a different treatment. Twenty branches were used. These had a total of 1670 emasculated and hand-pollinated blossoms more or less evenly distributed among treatments and controls. The treatments were applied at random within the selected trees as well as being randomized on a given tree.

On April 26, 1957, another series of treatments was applied at the station, using SHA#6 as the pollen parent and Henderson as the seed parent. Twenty-three branches with a total of 1034 emasculated and hand-pollinated blossoms were used.

No temperature records were taken at the Station on the trees which were hand pollinated. However, in order to obtain a continuous temperature record for a short period in the various protectors used, two of each kind of protector were placed on a SHA#6 tree that was close to a source of electrical power. Thermocouple leads were connected to a continuous recording potentiometer. In addition, one of each kind of protector with a thermocouple inside was tied on a pole, with cross pieces to spread the bag, at the same level as the protectors in the tree. This was done to see what difference there might be between the air temperatures inside bags which contained plant material and those with none inside.

At the Merkle farm, temperatures inside the protectors were recorded between 7:30 and 8:00 each morning and between 3:00 and 3:30 each afternoon with the use of a portable potentiometer. In addition to the scheduled readings, the temperature was recorded at frequent intervals during the coldest periods of nights during which a temperature of 32° F. or lower was forecast.

After the protectors had been on a few days, it seemed that the enclosed branches might be damaged by high temperatures prevailing in some during the day, if the protectors were left on for an extended period. To determine the influence of the duration of coverage, two protectors of each kind used at the Merkle farm were removed at the end of one week. The remaining protectors at both locations were left on for a total of 3 weeks. Fruit set counts were made after the completion of the normal drop, and percentage of fruit set was calculated from these data.

In 1958, the same procedure was followed as in the previous season, using the same parents, the same trees, and the same types of protectors (polyethylene and waxed and unwaxed parchments) immediately after hand-pollination. Pollinations at the Merkle farm were made on April 19, using 25 branches having a total of 1692 emasculated and hand-pollinated blossoms.

At the station farm, pollinations were made on April 22 and 23 using 32 branches having a total of 2511 emasculated and hand-pollinated blossoms. All protectors were removed after five days because the experiments in 1957 showed that high daytime temperatures inside the protectors might be injurious. In addition, it was demonstrated that no frost protection was provided by these protectors.

Insulating Materials Tested for Frost Protection

Four types of bags were prepared from insulating materials in 1958 for use as frost protectors. One was made of 1.5 mil black polyethylene with aluminum foil attached to the upper side. Another was made of 1-inch fiber-glass with a heavy paper liner on the inside and aluminum foil on the outside. A variation of the latter was also tried, using an additional layer of aluminum foil on the inside under the paper liner. A third was made from a blanket type of material (shredded paper between two layers of heavy brown paper), and a fourth was made from two multilayered brown paper bags which fit inside each other with about ½-inch of air space in between the sides of the bags.

After removal of the three types of bags used for protection in the five-day period immediately following pollination, the treated branches at the Merkle farm were divided into two equal groups. One group was covered by the four types of frost protectors (Fig. 2) on nights during which a temperature of 32° F. or lower was expected, and the other group was left uncovered. The frost protectors were put on early in the afternoon before the night of a frost warning and removed the next morning. Inside and outside air temperatures were taken with thermocouples during these cold nights.

Fig. 2. Four types of frost protectors on a Perfection apricot tree.

Early in the spring of 1959, pollen from Henderson and SHA#6 apricots was placed on various media at temperatures ranging from 45° to 90° F. in order to study pollen germination and tube growth. The media used were 2 percent plain agar mixed in 15 percent sucrose solution, and distilled water.

In 1959, it seemed desirable to investigate the time between pollination and fertilization under field conditions. This was important because of an apparent lack of this information in the literature and because this information would shed further light on the time the pistils needed to be protected after pollination in order to obtain maximum benefit from protection.

As a result, another experiment was started on the morning of May 2, 1959. The blossoms on a number of Henderson apricot branches at the station were emasculated and then pollinated with SHA#6 pollen. At intervals of 4, 8, and 24 hours, and daily thereafter for three days, 12 to 24 pistils were collected at random from the Henderson branches. The pistils were crushed and stained in Lacmoid-Martius yellow, and the progress of pollen tube growth was observed under the microscope. In addition to the above observations, pistils were also collected from open pollinated flowers at one, two, three, four, and five days after full bloom from Perfection, SHA#6, and SHA#7 apricots which were in full bloom at the Merkle farm on May 1. Pollen tube growth was observed in these pistils in the same manner.

Peach Experiments

Essentially the same procedures used for the apricots at the Merkle farm were also followed there in all three seasons for peaches. Redhaven was the seed parent and Kalhaven, the pollen parent.

In 1957, pollinations were made on April 30, using 20 branches having a total of 2282 emasculated and hand-pollinated blossoms. All protectors remained on for two weeks. In 1958, pollinations were made on May 1, using 28 branches having a total of 2,105 emasculated and hand-pollinated blossoms.

The growth of pollen tubes in hand-pollinated pistils of peaches was observed for a period of 24 hours in 1959.

RESULTS AND DISCUSSION

Germination of Pollen in Vitro

In the 1959 experiments, Henderson pollen germinated poorly in distilled water. This pollen, on agar or in sucrose solution, began to germinate in less than 1 hour at 80 to 90° F., but required 2 hours at 70° F. and longer at lower temperatures. However, the rate of pollen tube growth and the germination were best at 70° F. and were poorer at higher or lower temperatures. Pollen grain and tube bursting were greatest at 90° F. and decreased with decreasing temperatures over the test ranges of 45° to 90° F. Only an occasional grain or tube burst at 45° or 50° F. SHA#6 pollen did not germinate in distilled water and did not grow well in either of the two other media used.

Time Interval Between Pollination and Fertilization

In the case of the hand-pollinated Henderson X SHA#6 apricot crosses, the pollen was just beginning to germinate at 8 hours after pollination. At one, two, and three days after pollination, the bulk of the pollen tubes were, respectively, ¼, ½, and ¾ of the distance down the style. After 4½ days, many tubes could be traced into the ovary.

In the open pollinated varieties of apricots (Perfection, SHA#6, and SHA#7), occasional tubes could be traced into the ovary at three days after pollination, and many were visible in the ovary after four days. Many pollen tubes were visible in the styles of these varieties while less were visible in the hand-pollinated Henderson variety.

The time between pollination and fertilization of the Redhaven peach was about the same as for apricots, or 3 to 4 days under the conditions of the experiments. Day temperatures were usually in the 70's, and night temperatures were usually in the 60's during these experiments.

Experiments with Protectors

Weather During Protection Period

When the apricot pollinations were made at the Merkle farm in 1957, the work was interrupted by 4 hours of rain giving .70 inches of moisture. A 16-hour period of rainy weather delivering .70 inches of rain followed immediately after the apricot pollination work at the station farm.

The period of protection in 1957 covered approximately three weeks—the apricots being covered about one week earlier than the peaches. The weather during the first week was generally partly cloudy, warm, and windy. During the third week it was generally cloudy and warm with low winds. During the period of protection, there were three nights with temperatures below 32° F. at the Merkle farm, but none at the station.

Apricot pollination work in 1958 was stopped at the Merkle farm by rain after 25 branches had been completed. Precipitation amounting to .66 inches fell over a 19-hour period. At the station, pollinations were made on two days. About 3 hours after pollinations were completed on the second day, .77 inches of rain fell over a 15-hour period. The temperature during both days was between 45 and 50° F.

In 1958, there were protectors (polyethylene, waxed, unwaxed)

on either peaches or apricots at one or the other of the two test locations during a 2½ to 3-week period. During this period, the weather was cool, averaging 59-60° F. during the day. It was generally windy, and partly cloudy to cloudy. There were no temperatures below 32° F. while the protectors were on the peaches or apricots at the Merkle farm. However, two frosts occurred, three and four days after pollination, while the protectors were on the apricots at the station.

The weather at peach pollination time during both seasons was clear, cool, windy.

Temperature in the Protectors

During the day, the temperatures in the three types of protectors which were used immediately after pollination were invariably higher than the outside air temperature (Fig. 3). The difference between inside and outside temperature was dependent on weather conditions. On one occasion when the weather was warm, there was a difference of 28° F. between the outside and inside temperatures of one polyethylene protector. The extremes, however, were not usually this great, especially those of the unwaxed and waxed protectors. On cool, cloudy days, the temperatures in the protectors were only 2 or 3 degrees warmer than outside temperatures. On warm, cloudy days, there was usually a difference of 10 to 15 degrees between the two temperatures. The average temperatures at the 3:00 to 3:30 P.M. readings were highest for polyethylene, followed by unwaxed parchment, with waxed parchment coolest. All averaged higher than the control.

As shown in Fig. 3, temperatures in all protectors were lower at night than outside temperatures. The polyethylene protectors had the lowest minimum, followed by the waxed and unwaxed protectors which were about the same but about 2 degrees warmer than the polyethylene and still cooler than outside temperature. On nights with temperatures below 32° F., the polyethylene protectors averaged about 3 degrees F. colder than outside; the waxed and unwaxed protectors averaged 2 degrees colder. Temperatures were higher inside during the day and lower at night, even though no plant materials were enclosed, as indicated by the continuous records obtained from protectors supported on poles at the station.

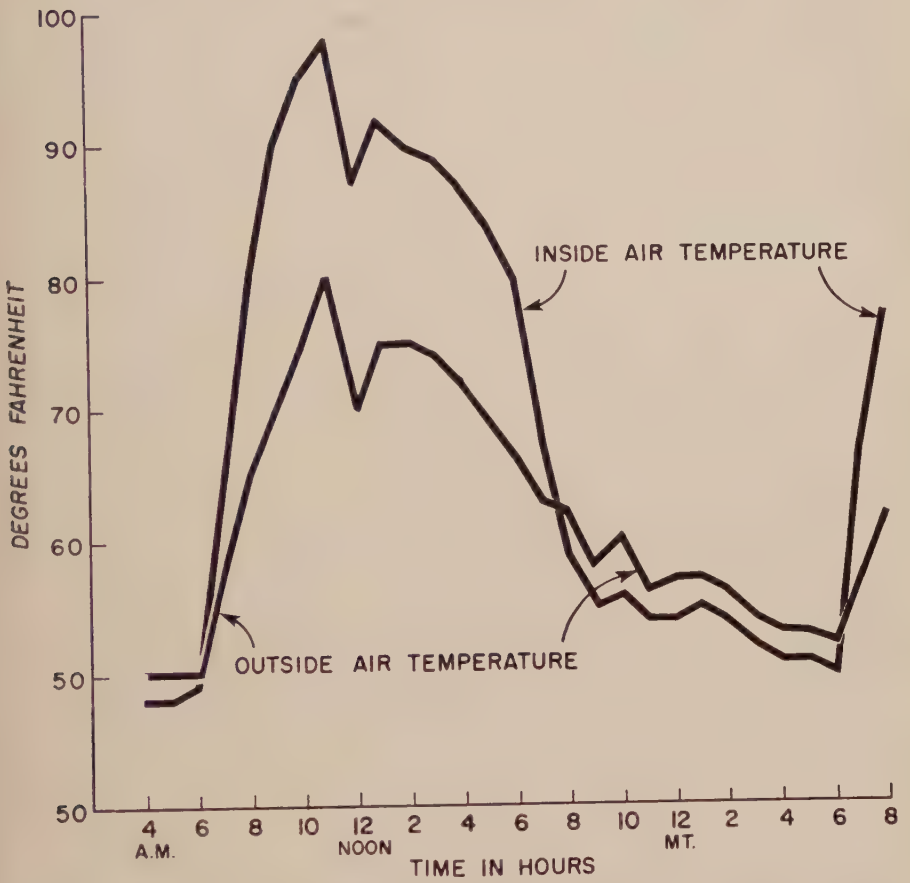

Fig. 3. Average air temperature within protectors on apricot branches compared to outside air temperature over a 28-hour period (April 30, 4 A.M. to May 1, 8 A.M.). Protector air temperatures were consistently above outside air temperatures during the day and below outside air tempearture during the night.

Effect of Polyethylene, Waxed, and Unwaxed Protectors on Plant Material Within the Protectors

The only adverse effect observed on the leaves was on apricots, where the branches were enclosed in polyethylene bags for three weeks. These leaves were small, necrotic, and few in number compared with those on untreated branches. This effect was noticeable for several weeks. The leaves on apricot branches covered for one week or less and on peach branches covered for two weeks or less were normal.

The only damage to the fruit itself that was observed was caused by low inside temperatures on some frosty nights when the protectors were on. On these nights, the inside temperature was enough colder (2-3 degrees in the case of polyethylene) to kill the fruits, while those on the outside were not injured.

There were generally wide differences in fruit set in response to the polyethylene, waxed and unwaxed protectors (Table 1 and Fig. 4). In 1957, fruit set in the protectors, which were left on apricots for three weeks at the Merkle farm, was 0, 2.9, 5.9, and 41.0 percent for polyethylene, waxed and unwaxed protectors, and the control, respectively. Average figures for the one-week treatment are given in Table 1, as are figures for the experiment at the station, where the protectors were all on for three weeks.

TABLE 1—Average percentage fruit set of apricots and peaches in three types of protectors during 1957 and 1958

	Type of protector			
	Poly-ethylene	Waxed parchment	Unwaxed parchment	Control
Apricots				
Merkle farm				
1957 (covered 1 week).....	29.9	40.1	37.5	41.0
1958 (covered 5 days).....	9.2	16.8	4.3	6.9
Station				
1957 (covered 3 weeks).....	3.7	33.9**	31.7**	11.1
1958 (covered 5 days).....	1.1	†13.4**	8.1**	2.1
Peaches				
1957 (covered 2 weeks).....	1.5	12.8	‡24.9	8.4
1958 (covered 5 days).....	7.2	18.7	29.8*	11.3

*Greater than control at 5% level.
**Greater than control at 1% level.
†Greater than unwaxed at 5% level.
‡Greater than other treatments at 1% level.

In the experiments on apricots at the Merkle farm in 1957, only one control branch was rained on (.70 inches) immediately after pollination, while at the station all controls received this amount in a shower starting immediately after pollination. There was a marked difference in the fruit set of the controls at the two locations largely because of this one factor. The differences in response from the 3-week treatments between the two locations were probably due to two factors, differences in maximum temperatures and frost.

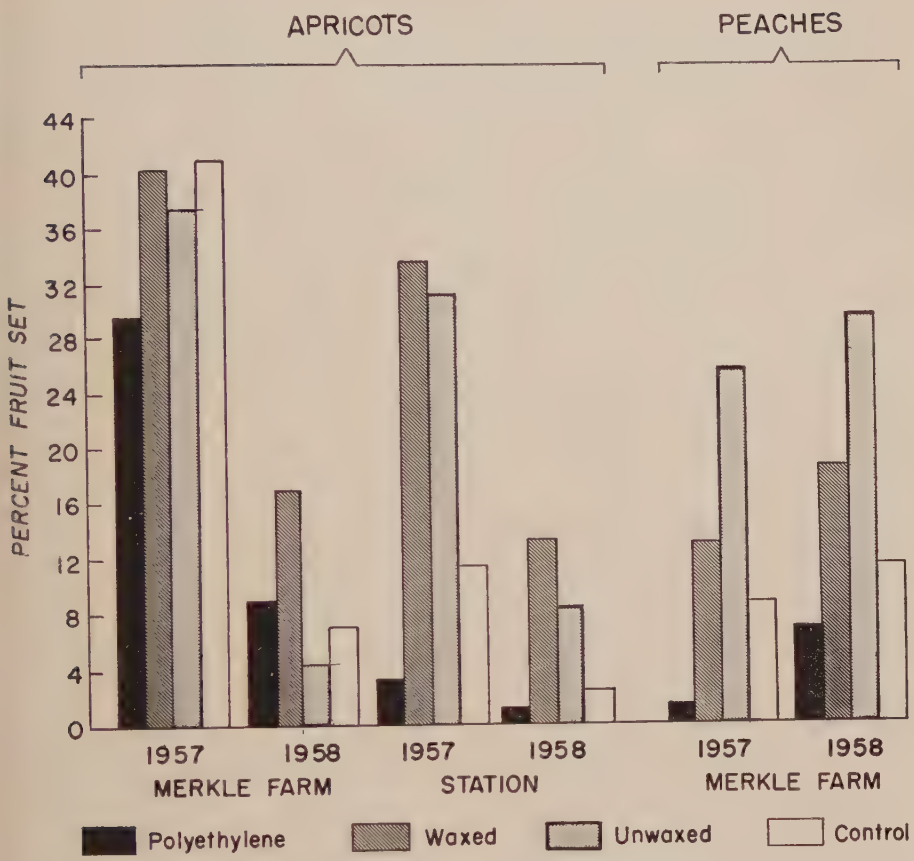

Fig. 4. A comparison of average fruit set from three types of protectors and control.

Average temperatures were lower by 4 or 5 degrees or more during warm weather at the station, which is only a few hundred feet from Lake Michigan. However, it was even too hot in the polyethylene protectors at the station, and a poor set of fruit was obtained.

In addition, fruit set in the other types of protectors at this location would probably have been better if the protectors had been removed much earlier. At least one, and possibly three, frosty nights while the protectors were on at the Merkle farm, caused a reduction in fruit set. Temperatures were cold enough to kill the young fruits inside the protectors, because of lower inside temperatures, without harming those outside.

The average fruit set for apricots in 1958 is given in Table 1. The reason for the low precentage set for the unwaxed protectors at the Merkle farm was not apparent. The reason for a generally lower set in 1958, as compared with 1957, was probably extremely poor weather following pollination in 1958. There were no frosts during the treatment period at the Merkle farm, but three such nights occurred after protector removal. Only one cold night, having a 25° F. minimum, appeared to harm the fruits, and this did considerable damage. Two frosty nights occurred during the treatment period at the station. These frosts damaged the fruits inside the bags but did not appear to harm those which were uncovered. The greatest harm appeared to be to fruits covered by polyethylene.

The average fruit sets of peaches in 1957 and 1958 are given in Table 1. As mentioned before, it was cool and windy during the period of fruit setting during both years.

The data in Table 1 show that it would not be wise to use polyethylene bags for this purpose. The data also show that the waxed parchment protectors gave the best results for apricots while unwaxed parchment was best for peaches. A definite explanation for this difference was not apparent.

The unwaxed and waxed parchment protectors provided a microenvironment which was favorable for fruit setting in the following ways:

1. Protection of the exposed pistils from rain. The results of the apricot experiments showed that rain shortly after pollination can reduce fruit set. Data were obtained from control branches which were rained on immediately after pollination, 3 hours after, and 18 hours after pollination. In every case except the latter, fruit set was reduced whether the temperature was warm or cool. Besides the above data, microscopic examination of pistils indicated that it was relatively easy to float pollen off the stigma with a drop of water before the pollen had germinated. In addition to the washing away of pollen, rain may dilute stigmatic secretion (Hedrick, 1908, and Wellington et al., 1929) and delay pollen germination. Several hours delay in germination could reduce the number of fertilized pistils.

2. Higher day temperatures during cold periods. Since many investigators have reported delayed pollen germination and slow pollen tube growth during periods of cool temperatures (1, 3, 4, 5), any increase in temperature during cold weather would be likely to in-

crease the probability of fruit setting. During cool, clear days, the increase in temperature provided by the waxed and unwaxed protectors may be 5-10° F. Even on cloudy days, the increase in temperature may be 4 to 5° F. However, on very warm days, inside temperatures may be actually too hot.

3. Wind protection. A number of investigators have indicated that drying winds cause stigmatic secretions to evaporate and dry prematurely, thus preventing pollen germination (Dorsey, 1919, Gardner et al., 1952, Hedrick, 1908, and Wellington et al., 1929). The protectors entirely eliminated this hazard by providing protection from the wind, in addition to providing higher relative humidity.

Since most of the pistil is exposed after emasculation and it is subjected to the effects of adverse weather, any one or all of the above benefits may be very important in increasing fruit set, especially when the weather is unfavorable for fruit setting. The experiments indicated that bagging may not be necessary during extremely good weather. Since unexpected rain may occur, however, the branches should probably be covered for the first 12 to 24 hours following pollination, if the temperature is not too high. Under average conditions, some benefit may be expected from protecting the branches for 3 to 4 days following pollination, as this is the approximate time required for fertilization. If the weather is cool, one or two days longer may be beneficial, but it does not seem probable that more than that would be needed.

If frosts are predicted, these protectors should be removed, because the inside temperatures may be colder than outside. Late spring frosts are often just on the borderline of that which will kill peach and apricot pistils. The one or two degrees F. lower temperature inside the protectors may be just sufficient to kill many of the pistils and young developing fruits.

Value of Frost Protectors

In contrast to the types of protectors used immediately after pollination to increase fruit set, it did not appear that the frost protectors wuold merit the time and expense involved in preparation and application. They seemed to have little, if any, protective value against frost.

SUMMARY

Three types of 2′ x 4′ bags—clear polyethylene, waxed white parchment, and unwaxed white parchment—were tested in the field in 1957 and 1958 to determine their value for increasing fruit set on peach and apricot branches having emasculated and hand-pollinated blossoms. These bags were applied immediately after pollination to overcome the adverse effects of cold, rainy weather during this period of time.

Polyethylene bags were of no value, but waxed and unwaxed parchment bags, in most cases, produced significant increases in fruit set over control branches. Apricots produced more fruit in waxed bags, whereas peaches were most productive in unwaxed bags.

It was found that five days would ordinarily be long enough to provide protection after pollination. This period might be lengthened if the weather was cool, or reduced if it was too warm. Temperatures in all bags were usually 10-15° F., or more, warmer during the day and 2-3° F. colder during the night than outside temperatures. The benefits derived from bagging were found to be the result of protection from rain and wind as well as the result of increased temperatures during cool weather.

In 1958, special frost protection bags were applied after the polyethylene, waxed, and unwaxed bags were removed, but only during the nights when temperatures below 32° F. were forecast. Four types of bags were tried, but only those made with 1-inch fiberglass covered by aluminum foil showed any promise, and even this was questionable. Considering the problems involved, it did not seem likely that any of these special types of bags would be worth the time and expense involved in their use.

Laboratory tests during 1959 showed that Henderson apricot pollen on agar or in sucrose solution began germinating in less than one hour at 80 or 90° F. However, germination was higher, and pollen tubes grew faster at 70° F. with poorer results at higher or lower temperatures. Results under field conditions may not necessarily be the same, however.

Field experiments in 1959 showed that the time between pollination and fertilization would be from 3 to 4 days for Henderson X SHA#6 crosses and for open pollinated Perfection, SHA#6a, and SHA#7 apricots. Limited observations indicated that this would also be true for Redhaven X Kalhaven peach crosses.

LITERATURE CITED

Dorsey, M. J. (1919). Relation of weather to fruitfulness in the plum. Jour. Agr. Res. 17: 103-126.

Gardner, V. R., F. C. Bradford, and H. D. Hooker (1952). Unfruitfulness associated with external factors. *The Fundamentals of Fruit Production.* 3rd ed. McGraw-Hill Co., New York. pp. 669-685.

Hedrick, U. P. (1908). The relation of weather to the setting of fruit. N. Y. (Geneva) Agr. Expt. Sta. Bul. 299: 59-138.

Knowlton, H. E. and M. P. Sevy (1925). The relation of temperature to pollen tube growth in vitro. Proc. Amer. Soc. Hort. Sci. 22: 110-115.

Wellington, R., A. B. Stout, O. Einset, and L. M. Van Alstyne (1928). Pollination of fruit trees. N. Y. (Geneva) Agr. Expt. Sta. Bul. 577: 1-54.

STORAGE OF HIGH MOISTURE CORN IN UPRIGHT SILOS AND ITS FEEDING VALUE FOR DAIRY COWS

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IN THE FALL OF 1957, a project was initiated at Michigan State University in cooperation with the Michigan Association of Silo Manufacturers to study the feasibility of storing high moisture corn grain in conventional upright silos. The feeding value of the ensiled corn was determined by feeding it to dairy cows and comparing results from its use with those obtained from feeding similar corn grain dried artificially to 14 percent moisture.

Results for the crop years of 1957 and 1958 are presented in this paper. The general plan of the experiment was the same for each year.

PROCEDURE

Three concrete stave silos, 12 feet in diameter and 12-½ feet high with standard wooden doors and aluminum roofs, were constructed near the main dairy barn as shown in Fig. 1. Only ordinary materials, which received no special treatments, were used in the construction.

Each year the corn grain stored in the silos was harvested from a single large field in a randomized manner. In 1957, all of the corn was harvested when it contained 40 percent moisture. Batches of appropriate size were then dried to different moisture contents for storage, including one batch that was dried to 14 percent moisture and stored dry to serve as a basis of comparative performance in the feeding trials.

After drying, the corn was ground through a portable hammer mill with a ½-inch screen and elevated into the silos with an ordinary grain and forage conveyer. The silos were filled about one-half full.

ARTICLE 43-6

Fig. 1. Elevating high-moisture corn into the experimental concrete stave silos.

The upper surfaces of the piles were leveled off, and covered with a plastic sheet. All the corn was harvested between October 25 and November 6, and feeding was begun January 10.

In 1958, all the corn was harvested and stored between October 16 and 29. Each batch was ground through a burr mill to a fineness approximately that obtained with a hammer mill equipped with a ½-inch screen. It was then stored in the silos in a manner similar to the first year, except that the ear corn silo was filled to capacity. As in 1957, one batch of corn was dried to 14 percent moisture and stored dry for use as a comparison control in the feeding trials. Feeding tests were begun on January 10.

During the feeding trials, the amounts of spoilage in the different silos was determined. The kinds and moisture contents of the corn stored in the different silos, and the amounts of spoilage that occurred in 1957, are summarized in Table 1.

During the storage period, temperatures inside the pack were measured by thermocouples fastened 2 feet apart, vertically on a pole at the center of each silo.

In the milk production trials, all cows were fed alfalfa hay at a rate of 2.0 pounds per 100 pounds of body weight. Enough corn was

then fed to meet the TDN requirement of the animal. Supplemental minerals (trace mineral salt and dicalcium phosphate) were fed free choice. No supplemental protein was fed since sufficient protein was supplied by the alfalfa hay. Amounts of corn that would furnish the same pounds of dry matter were fed in each case and no allowance was made for the cobs in the ear corn.

In addition to the milk production trials, one set of digestion trials with the 1957 crop and passage trials were conducted each year with high-moisture unground shelled corn. The first passage studies were run on corn different from that used for the milk production trials, but it also was stored in a conventional upright silo. The second passage trial was run on the same unground shelled corn as was fed in the 1958 milk production trials.

RESULTS AND DISCUSSION

Preservation

Both years when the silos were opened, about three months after storage, a small amount of corn was spoiled in the center of each silo around a pole used to support the thermocouples. The remainder of the corn still retained much of its original color and appeared to have preserved perfectly. The odor of the corn indicated that some type of fermentation had occurred.

Each year as the feeding trials progressed some trouble was experienced with top spoilage. During the first year, only three cows and during the second year only seven cows were fed from each silo, except that 10 additional steers were fed from the ear corn silo in 1958. With the latter silo, very little spoilage occurred. Spoilage occurred least with the ground 26 or 32 percent moisture shelled corn, followed by the ear corn, 40 percent moisture ground shelled corn, and then the 32 percent moisture unground shelled corn. Spoilage was so rapid with the 32 percent unground shelled corn that this type of product would present a real problem unless a large number of cattle were being fed.

In these experiments, the top spoilage was managed in such a manner as to keep the amount of unfed corn at a minimum, except in the case of the unground shelled corn where a considerable amount of corn was lost. The experience indicates that 20 to 25 cows would be required to minimize the spoilage with either ear corn or ground shelled corn stored in silos of this diameter.

In the first year's work, the feeding trials were completed in May and the plastic covers were replaced. The covers were again removed in August and any mouldy corn was removed. The problem of top spoilage, when feeding during the hot weather, was not any greater than during cold weather. The total amount of spoiled corn is shown in Table 1 for the 1957 crop and all of this occurred when the silos were reopened in August for additional feeding.

TABLE 1—Kinds and moisture contents of corn stored in 1957 and 1958 and the amount of spoilage in 1957

Silo No.	1	2	3
1957 crop:			
Kind of corn	Ground shelled	Ground shelled	Ground ear
Percent moisture	26	40	36
Lbs. of spoilage	530	1825	19
1958 crop:			
Kind of corn	Ground ear	Ground shelled	Unground shelled
Percent moisture	32	32	32

Milk Production

Three cows in the first year and seven cows in the second year were allocated per group. The results of the individual trials are presented in Tables 2 and 3 with the combined results for the two years in Table 4. In order to combine the results of Trials 2 and 3, the 26 percent moisture ground shelled corn fed in Trial 1 and the 32 percent ground shelled corn from Trial 2 were considered to be similar.

The results of the milk production trials during the first year (Table 2) indicate little difference in the performance of cows fed the dry corn, low moisture shelled, or the ear corn, but all were much better than that cows fed the 40 percent ground shelled corn. Cows fed the 40 percent ground shelled corn produced less total and 4 percent FCM (fat corrected milk) than those fed the other three types of corn. This group of cows also had a much greater decline in 4 percent FCM and gained less in body weight. It is difficult to explain the poor performance of cows fed this high moisture corn, because the corn was consumed readily and digestion trial data indicated a satisfactory TDN value.

In the second trial (Table 3) the performance of cows fed the 32 percent moisture ground shelled corn was somewhat below that of the

other groups of cows. There were two cows in this group that did not perform satisfactorily from the beginning of the trial which contributed greatly to the subnormal performance of this group. Actually, the rate of decline in milk production of all groups of cows was less than is normally expected for cows in declining lactation. The body weight loss of cows fed the unground shelled corn indicates that this ration was suboptimum. This was probably due to the high passage of whole corn as was evident from an inspection of the feces from these cows.

The combined results of the two years' work (Table 4) show that the performance of all groups of cows was satisfactory and that the feeding value of both types of high moisture corn was comparable to that of the dry corn. The decline in milk production of the cows fed the ground shelled corn was slightly more than in the other groups of cows, but again all groups declined at a slower rate than is normally expected. The performance of cows fed high-moisture ear

TABLE 2—Results of feeding high moisture corn to dairy cows—1957 crop

Kind of corn(a)	Regular	High shelled	Low shelled	Ear corn
Number of cows	3	3	3	3
Length of test (days)	112	112	112	112
Initial actual milk production (lb.)	35.3	39.0	36.2	37.1
Initial butterfat test (%)	3.4	3.5	3.8	3.3
Initial 4% FCM (lb.)	31.8	35.8	34.5	33.1
Av. actual milk production (lb.) over 112 days	29.3(30.5)	26.8	29.7(30.4)	27.9(29.5)
Av. butterfat test (%)	3.8(3.8)	3.8	4.0(4.0)	3.8(3.7)
Av. 4% FCM (lb.)	27.7(28.9)	25.6	29.3(29.9)	26.9(28.1)
Percent decline in actual milk production over 112-day trial	29.2(28.6)	46.2	24.3(22.4)	36.9(35.3)
Percent decline in 4% FCM	26.1(22.6)	44.7	20.9(18.6)	29.6(28.1)
Av. body weight gain (lb.)	25.4(22.7)	5.5	17.6(13.7)	24.7(19.3)
Feed data				
Hay consumption (lb.)	25.3	26.3	27.8	25.7
Corn consumption (lb.)	8.0	11.4	9.5	10.9
Dry matter of corn (%)	83.02	60.52	73.60	65.85
Corn dry matter consumed (lb.)	6.64	6.90	6.99	7.18
Chemical composition as fed (%)				
Dry matter	83.02	60.52	73.60	65.85
Moisture	16.98	39.48	26.40	34.15
Crude protein	9.43	6.85	8.80	6.83
Crude fiber	2.40	1.76	1.52	6.32
Ether extract	3.08	2.22	2.85	1.87
Ash	1.60	1.10	1.23	1.22
Nitrogen-free extract	66.51	48.59	59.20	49.61
Chemical composition as stored (%)				
Dry matter	83.02	59.20	74.14	63.91
Moisture	16.98	40.80	25.86	36.09
Crude protein	9.43	6.42	8.16	6.01
Crude fiber	2.40	1.65	1.65	6.17
Ether extract	3.08	1.88	3.11	1.34
Ash	1.60	1.05	1.18	0.98
Nitrogen-free extract	66.51	48.20	60.04	49.41

(a) All corn was ground.
( ) 90-day values.

TABLE 3—Results of feeding high moisture corn to dairy cows—1958 Crop

Kind of corn	Regular	Ground shelled	shelled(*a*)	Ground ear
Number of cows	7	7	7	7
Length of test (days)	90	90	90	90
Initial actual milk production (lb.)	38.9	39.5	39.0	38.7
Initial 4% FCM production (lb.)	37.4	39.3	38.7	37.9
Av. actual milk production over 90-day trial (lb.)	36.1	33.7	33.6	35.4
Av. butterfat test (4%)	3.7	3.9	4.0	3.9
Av. 4% FCM production (lb.)	34.3	32.9	33.5	34.6
Av. per cent decline in 4% FCM production	11.0	24.9	13.2	11.3
Av. body weight gain (lb.)	13.3	32.0	24.4	1.4
Feed data				
Hay consumption (lb.)	23.5	24.2	24.7	25.9
Corn consumption (lb.)	11.8	15.3	14.8	14.9
Corn dry matter consumed (lb.)	10.0	10.6	10.2	10.3
Chemical composition as fed (%)				
Dry matter	84.96	69.17	69.23	69.02
Moisture	15.04	30.83	30.77	30.98
Crude protein	8.44	6.97	7.14	6.40
Crude fiber	2.00	1.73	1.56	4.41
Ether extract	4.12	3.19	3.68	2.75
Ash	1.24	0.98	1.04	0.95
Nitrogen free-extract	69.16	56.30	55.81	54.51
Chemical composition as stored (%)				
Dry matter	84.96	66.97	67.35	67.41
Moisture	15.04	33.03	32.65	32.59
Crude protein	8.44	6.56	6.59	6.01
Crude fiber	2.00	1.56	1.74	5.27
Ether extract	4.12	2.83	3.23	2.54
Ash	1.24	0.94	0.97	0.93
Nitrogen free-extract	69.16	55.08	54.82	52.66

(*a*) 56-day trial due to spoilage.

TABLE 4—Summary of trials 1 and 2 relative to feeding high moisture corn to dairy cows (1957 and 1958 crops)

Kind of corn	Regular	Ground shelled	Ear corn
Number of cows	10	10	10
Length of test (days)	90	90	90
Initial actual milk production (lb.)	37.8	38.5	38.2
Initial 4% FCM production (lb.)	35.7	37.9	36.5
Av. actual milk production over 90-day period (lb.)	34.4	32.6	33.6
Av. buttterfat test (%)	3.7	4.0	3.8
Av. 4% FCM production (lb.)	32.7	31.8	32.6
Av. percentage decline in 4% FCM	14.5	23.0	16.3
Av. body weight gain (lb.)	16.1	26.5	6.8
Feed data (average per day)			
Hay consumption (lb.)	24.0	25.3	25.8
Corn consumption (lb.)	10.7	13.6	13.7
Dry matter of corn (%)	84.5	71.4	66.5
Corn dry matter consumed (lb.)	9.0	9.1	9.2

corn in these studies was remarkably good in view of the fact that ear corn is generally regarded to be slightly lower in feeding value than shelled corn. In no case was there any indication that the high-moisture corn was not palatable and appetizing.

Digestion Trial

The results of the digestion trials are shown in Table 5. All of the coefficient and TDN values are 10 to 15 percent low. No explanation is available since no difficulty was encountered in conducting these trials. The coefficients were obtained by difference after running a trial with a standard hay. The coefficients on the standard hay were very high which probably accounts for the low values obtained for the corn grain. The only conclusion that might be drawn from these data is that there does not appear to be any great differences among the various high-moisture corns and all were similar to the coefficients and TDN value for the dry corn.

TABLE 5—Digestion coefficients and TDN values of high-moisture corn

	Dry matter	Crude protein	Ether extract	NFE	TDN(*a*)
Kind of corn			Percent		
Dry corn	72.2	44.2	62.1	85.8	66.7
26% ground shelled	60.2	26.1	60.7	84.0	64.2
39% ground shelled	60.8	38.2	62.5	84.3	65.2
36% ground ear	68.4	40.2	60.6	85.3	63.2

(*a*) 15.5% moisture basis.

Passage Studies

The results of the two passage studies are shown in Table 6. In the first trial, the passage of whole corn was low with both the dry and high-moisture unground shelled corn. The passage of the high-moisture corn was slightly less than that of the dry corn. In the second trial, the passage of undigested corn was approximately the same with both types of corn and both were considerably higher than in the first trial. Results from the passage trials indicate that high-moisture corn should be ground before feeding to cows. The chemical composition of the corn passed into the feces was similar to that which was fed, showing that very little, if any, digestion had occurred.

TABLE 6—Results of passage studies of unground shelled corn

Kind of corn	Dry corn	High-moisture corn
	Percent	
Trial 1—Cow No.		
A-71	10.1	7.1
A-116	14.4	8.1
A-127	11.1	8.4
A-131	6.6	0.0
Average	10.6	7.9(*a*)
Trial 2—Cow No.		
A-71	8.7	16.8
568	20.9	21.7
T-17	12.6	26.8
T-22	15.7	14.5
Average	14.5	20.0

(*a*) Only used three values in average.

Temperatures

The recorded temperatures are shown in Fig. 2. The maximum temperature occurred from six to 10 days after filling. The temperatures the second year were all higher than the first year, even though the outside temperatures were considerably lower.

SUMMARY AND CONCLUSIONS

The results of these studies on the feeding value of high-moisture corn stored in conventional upright silos show that this practice offers farmers in the northern states an alternative method of storing and utilizing such corn. The following conclusions are based on two-year results:

1. High-moisture corn can be stored satisfactorily in conventional upright silos with little spoilage loss by covering it with a plastic sheet until the feeding period is started.
2. Once the silos are opened, the corn must be fed at a rate rapid enough to avoid excessive spoilage. At least 20 to 25 dairy cows should be fed from a 12-foot diameter silo.

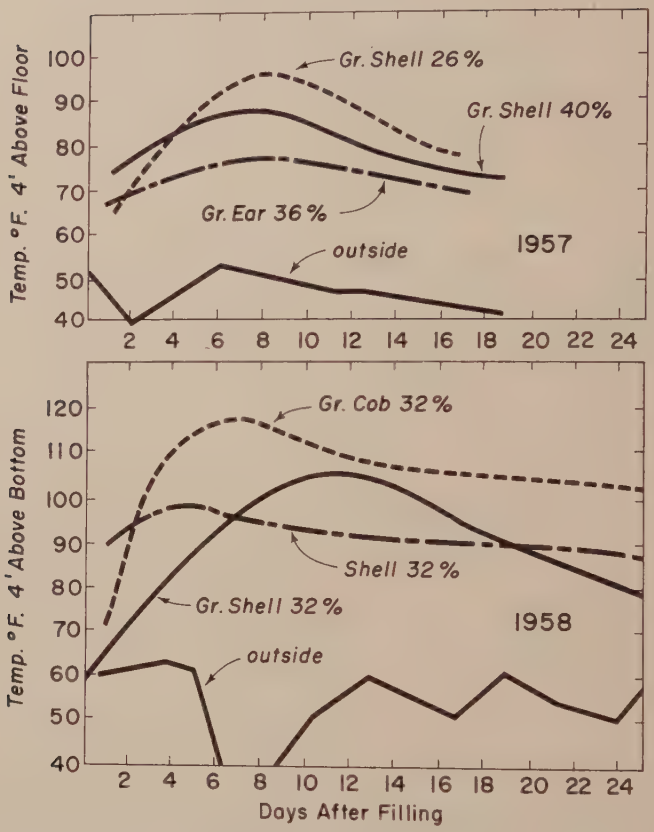

Fig. 2. Temperatures recorded in HMC stored in concrete stave silos.

3. Spoilage was least with corn containing from 25 to 35 percent moisture.
4. Based on its dry matter content, the feeding value of high-moisture corn appears to be equal to, but not greater than, that of dry corn.
5. Results of passage trials with unground shelled corn indicate that this type of corn should be ground before storage.

TIME REQUIREMENTS IN FEED MILL OPERATIONS

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DEPARTMENT OF AGRICULTURAL ECONOMICS

THE FEED AND GRAIN BUSINESS has long been important to Michigan and it may become more important in coming years. Northward movement of the upper Corn Belt boundary and development of the St. Lawrence Seaway are two recent and potentially influential changes having important implications for Michigan agriculture.

It is generally believed that the Michigan feed and grain elevator business is now in a period of adjustment which will continue until (1) the existing number of local elevators is greatly reduced and (2) many elevators are more appropriately located with respect to potential business and outside of urban areas.

When feed mill and elevator changes are made, it is important that those who make decisions as to plant layout, equipment, etc., have as much information as possible on which to base their decisions. This is a progress report which has been developed from studies being made of costs and efficiencies in grain elevator and feed mill operation. It concerns time requirements for performing some of the operations in a feed mill. Future reports are expected to develop costs of operation of feed mills and grain elevators.

Ten feed mills, having a wide range in size and representing various types of ownership—single proprietor, partnership, corporation, and cooperative—were included in this study. They were chosen from a larger sample to obtain desired size and ownership characteristics.

Times for positioning the delivery vehicle, preparation of vehicle and receiving area for unloading, unloading the grist, moving it out of the receiving pit or bin, grinding, and bagging and load-

[1] Noel Stuckman, formerly graduate research assistant, Mich. State Univ., now assistant coordinator of commodity relations, Michigan Farm Bureau, assisted in collection of much of the data included in this report.

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ing are included in this report. Comparison of time requirements in various mills serves to determine the factors in mill layout and operation that may reduce time required.

Positioning

All the time required to move the carrier from a position at the edge of the receiving area to the position from which it was unloaded was included in "positioning". The timing commenced when the carrier entered the unloading area and ended when the vehicle was properly positioned for unloading. It included actions such as centering the vehicle in the unloading area, stopping, backing or any movement to position the carrier so as to enable the dumping of the load directly into the receiving pit.

If a cradle-type hoist was used, it included positioning the vehicle's front wheels in the cradle, raising the cradle off the floor and moving the vehicle to the proper position over the receiving pit. When a tilt-bed hoist was used, it included all the actions necessary to position and secure the vehicle on the table.

Positioning time was found to vary with type of carrier, as shown in Table 1. The times given in this table represent unweighted averages, over mills, of the time requirements for the given carrier within each mill.

TABLE 1—Positioning times by carrier type

Carrier	Pickup truck	Flat-bed truck	Dump truck	Tractor and trailer	Auto and trailer	Auto
Time (min.).....	.58	.67	.60	.77	.44	.20

Positioning time was found to be very low for an automobile which brought a few bags of grist, usually in the trunk, because it was unnecessary to position the vehicle as accurately as with other vehicles. It also was found that a trailer could be positioned more rapidly with an automobile than with a tractor, although a large part of this difference is more apparent than real. The trailers pulled by autos were usually smaller and two-wheeled, while the tractor-

pulled trailers were larger and four-wheeled. Most of the tractor-pulled trailers involved use of a hoist, while the car-pulled trailers usually did not.

If the times were presented on a "per ton" or other weight basis, the results would be more favorable for the tractor. Pickup trucks, flat-bed trucks and dump trucks were found to require approximately equal times for positioning. Table 2 gives positioning times and the rank from low to high for the elevators included in the study.

TABLE 2—Positioning times and rank by sample mill

Elevator number	1	2	3	4	5	6	7	8	9	10
Average positioning time (min.)	.49	.77	.65	.89	.33	.58	.41	.46	.58	.60
Rank (low to high time)	4	9	8	10	1	5-6	2	3	5-6	7

There were some obvious differences in these feed mill receiving operations which accounted for many of the differences in receiving times. Mill No. 5, which ranked first in positioning time, had a layout which allowed a short distance from the waiting area to the receiving pit (about 20 feet). The pit area was easily accessible and had an unusually wide door which cut to a minimum the need to twist and turn forward and backward to get into position.

This mill had one employee assigned to work closely with the receiving operation. This employee controlled the tilt-bed truck hoist, hydraulic rear wheel stops and hydraulically operated pit covering. The result was a smooth running receiving operation. It, of course, must be remembered that employee time was used to do some things often done by customers in other mills, i.e., operation of truck hoist and opening and closing of pit covering.

Mill No. 7 ranked second and also had a very low average positioning time. This, however, was due to the fact that the truck hoist was being used for grain receiving operations during this study and positioning included only the time to position the vehicle for unloading into a chute. No time for getting onto a hoist and ready to unload was included.[2] Mill No. 8 ranked third and had a receiving arrangement similar to No. 5. It did not have the hydraulically operated receiving pit cover and had a cradle-type hoist.

[2] It should not be inferred from this that a receiving chute has overall merit. The time saved in positioning is minor in comparison with time lost in unloading. See Table 4, where mill 7 ranks last in average unloading time for all grists.

Just as there are reasons for fast performance, there are also reasons for slow performance. Mills 3, 2 and 4, ranking 8, 9 and 10, respectively, have some things in common which explain their relatively long positioning time. No. 3 had a bean receiving operation at the driveway opening and the No. 4 receiving area was close to the street. Both receiving areas were therefore congested. Mills No. 3 and 4 had the receiving areas located at a greater than average distance from the mixing area, making it comparatively difficult for employees to assist in positioning. Mill No. 2 operated with one employee, who was usually busy elsewhere in the mill. In all three mills, the customer usually operated the hydraulic hoist.

Preparation

Preparation included all the activities involved in getting the pit and vehicle ready to unload after the vehicle was properly positioned. It included such things as removing or opening a tail gate, removing empty bags and other loose articles from the carrier, and lifting the door or grating over the pit. Table 3 gives the times and ranking for preparation.

TABLE 3—Preparation times and rank by sample mill

Elevator number	1	2	3	4	5	6	7	8	9	10
Average preparation time (min.)	.51	.38	.43	.96	.49	.51	.76	.55	.68	.48
Rank (low to high time)	5-6	1	2	10	4	5-6	9	7	8	3

There are many factors involved in preparation time determination. Two of these, ease of opening the receiving pit door and the amount of conversation between employee and customer, seemed to be most important. Preparation for unloading is performed almost exclusively by the customer and is therefore an activity over which the mill management has little control.

Unloading

Unloading time commenced at the completion of "preparation" and ended when all of the grain had been moved off the carrier and into the receiving pit. It was found to vary considerably according to method, as shown in Table 4, and to a lesser extent by mill.

TABLE 4—Unloading times and rank by sample mill

Method	Mill number										Average of all mills
	1	2	3	4	5	6	7	8	9	10	
	Minutes per hundredweight										
Loose grain, using hoist	.18	.25	.38	.21	.18	.22	....	.20	.22	.14	.20
Loose grain, using hand shovel	.57	....	....	....	.44	.36	.78	.53	.60	.84	.59
Loose grain, dump truck	....	.07	.05	.08	.05	.04	....	.10	....	....	.07
Bagged grain	.41	.48	.43	.61	.49	.61	.43	.43	.36	.35	.46
Average of all grists	.28	.23	.31	.20	.21	.26	.60	.23	.27	.36	.30
	Rank—low to high in minutes per hundredweight										
Loose grain, using hoist	3	8	9	5	2	7	....	4	6	1	
Loose grain, using hand shovel	4	....	....	....	2	1	6	3	5	7	
Loose grain, dump truck	....	4	2	5	3	1	....	6	....	....	
Bagged grain	3	7	4	9	8	10	6	5	2	1	
Average of all grists	7	4	8	1	2	5	10	3	6	9	

Grain was unloaded from a dump truck in a considerably shorter period of time than with any other method. However, the type of carrier used is under the control of the mill operator only when his trucks haul the grain. At the present time, this represents a small part of the total feed business in most mills. It may become more important in the future, and if so, will make it more profitable to install dumping mechanisms on company trucks.

Unloading with the aid of a hoist required less than one-half as much time as for bagged and hand dumped grain and one-third as much time as for hand shoveled grain. The type of hoist apparently had little effect on unloading time. Mills 1 to 4, 6, and 8 had cradle-type hoists and mills 5, 9 and 10 had tilt-bed type hoists.

While the sample is too small to draw definite conclusions, the average unloading time per hundred weight in the six mills with cradle-type hoists was .24 minute, and in the three with tilt-bed hoists, .18 minute. There are, of course, many factors other than hoist type involved in unloading time, such as existence and size of bins, grinding capacity, and whether or not the customers are waiting, which would cause the operator to hurry.

Although neither method is especially important in terms of total business, it is interesting to note that less time is required to dump grain from bags than to shovel it from a carrier. A high percentage of the customers include a few bags of grain on their loads, often because they desire two or more different grain mixes.

There are several things that influence the average unloading

time. These include (1) the speed at which the customers work, (2) the amount of grain dumped with a hoist or dump truck, (3) how well the customer has mixed loads organized on his carrier, and (4) how much assistance is given to customers by employees.

Mills 4, 5 and 8, ranked 1, 2 and 3 as having the lowest unloading time requirement per hundredweight, had three characteristics in common: (1) they were comparatively large firms having three or more employees, (2) they had comparatively high ratios of grain unloaded by hoist to grain in bags or shoveled from a carrier, and (3) most of the time during the study they were busy, as evidenced by one or more customers waiting to unload. In general, mills 3, 10 and 7, ranked 8, 9 and 10, were opposites of the first three mills in these characteristics.

Feeding

In this study, the time required to move the grain from the receiving pit was called "feeding time". Feeding time is important only when slowness of feeding delays customers in commencing the unloading of their grain.

The feeding rate, or the speed at which the grain can be removed from the receiving pit, is a function of the slope, size and speed of the shaker or chain drag in the bottom of the pit. However, grain can be moved quickly from the pit only when there are holding bins of sufficiently large capacity positioned to hold grain before entering the grinder and/or sheller. If there are no holding bins or if they are small, grain must be moved from the receiving pit at a rate not exceeding the grinder capacity.

Table 5 gives the feeding times per hundredweight of grain by sample mill. These times are the average for all grains and differ within mills for different grains. Corn and cob would generally move somewhat faster than the average, followed by oats and shelled corn. Grain mixtures were moved more slowly than any individual grain.

TABLE 5—Feeding time per hundredweight and rank by mill

Mill number	1	2	3	4	5	6	7	8	9	10	All mills
Average feeding time (min.)	.42	.40	.60	.71	.33	.28	.64	.30	.58	.45	.47
Rank (low to high times)	5	4	8	10	3	1	9	2	7	6	..

Mills 6, 8 and 5, which ranked 1, 2 and 3, all had large holding bins. Grain could thus be moved rapidly from the receiving pit to the holding bin to await grinding. Mill No. 5, however, used the holding bin only when grinding would be slow, that is, when a fine screen was used or when grinding hard-to-grind grains. Mill No. 3, which ranked 8, had a small holding bin. Mills No. 7 and 4, which ranked 9 and 10, had no holding bin. In these three cases, feeding was limited in speed by the grinding speed. In mills 7 and 4, grinding and feeding times were identical.

Grinding rate is determined by kind of grain being ground (corn, oats, etc.), condition of the grain (wet or dry), screen size (fineness of grind), grinder size (horsepower rating and screen area), and percent of capacity at which the grinder is operated.[3] To obtain independent measures of the effect of each of these things would require that within each mill each grain be ground separately using various screen sizes.

In addition, it would be necessary to determine the moisture content of the grain in each grist and the percent of capacity at which the grinder was being run. Since most grists are a combination of grains, ground as one, it was difficult to obtain a sufficiently large number of observations on each grain and screen size in a given mill to obtain reliable estimates of their effect on grinding speed. No estimates were obtained of the effect of moisture content and the percent of capacity at which the grinder was being operated.

While we cannot give precise estimates of the effect of various factors on grinding speed, we do have sufficient information to draw general conclusions based on individual mills. For instance, in mill No. 6, which had the highest average grinding output per minute—257 pounds—the corn and cob output was 210 pounds and shelled corn was 374 pounds. In this mill, the average[4] screen sizes were .42 inch for all grists, .53 inch for corn and cob and .17 inch for shelled corn.

Mill No. 5, which was nearly equal to No. 6 in grinding speed, had a grinding rate for all grists of 240 pounds per minute with an average screen size of .41 inch, while shelled corn and oats had grinding rates of 281 and 134 pounds and average screen sizes of .39 and .44 inch, respectively. Mill No. 8, which ranked 5th in grind-

[3] This includes the limitations that may result from poor condition of grinding equipment, including motors.

[4] Average screen size as used in this section refers to a weighted average screen size.

ing speed, had grinding rates and average screen sizes of 230 pounds per minute and .28 inch for shelled corn, 158 pounds per minute and .66 inch for corn and cob, 170 pounds per minute and .31 inch for oats, and 177 pounds per minute and .38 inch for grain mixtures. From these figures, it appears that shelled corn is the easiest to grind among these grains, followed by oats, with corn and cob most difficult.

Of course, the most obvious reason for differences in grinding rates among mills is the size and horsepower rating of the grinding equipment. Table 6 gives the average grinding rate, mill rank, and horsepower rating of equipment used in each of the mills. This table shows that the four mills having lowest time requirements for grinding 100 pounds of grain had horsepower ratings of 95 to 105. The remainder, with the exception of mill No. 9 which ranked eighth, had a total of 65 to 85 horsepower.

The ratio of grinding to feeding rates is one indication of how well a mill is organized to make full use of its grinding equipment, since a high grinding to feeding rate would minimize grinding delays caused by a wait for grain. This wait might occur between grists, for instance, if there is no backlog of unground grain to even out an uneven flow from the receiving pit.

Table 7 gives the grinding/feeding ratios and ranks them from high to low. It shows that mills with high grinding/feeding ratios typically have large—100 bushels or more—holding bins which

TABLE 6—Grinding time, rank, and horsepower rating by mill

Mill	Time in minutes per cwt.(*a*)	Rank	Horsepower rating			
			Hammermill	Crusher	Blower	Total
1	.48	3	75	5	15	95
2	.60	6	50		15	65
3	.53	4	75		25	100
4	.72	10	60		20	80
5	.42	2	75		30	105
6	.39	1	75		30	105
7	.64	7	50		20	70
8(*b*)	.56	5	60		25	85
			60	5	15	80
9	.66	8	103			103
10	.71	9	50		20	70

(*a*) Average grinding time for all grains and all screen sizes.
(*b*) Mill No. 8 has two grinders served from one receiving pit.

are used as "surge tanks" for their grinders. Mills with low grinding/feeding ratios have small bins or have no holding bins. Favorable grinding/feeding ratios and high grinding speeds do not necessarily occur in the same mills. A mill with small equipment, but a favorable ratio, indicates their receiving equipment is sufficient to enable the best use of their grinding equipment.

Table 7 also gives the kind of equipment each mill has to move the grain from the receiving pit to the holding bin or grinder. Mills ranked from 1 to 6 in grinding/feeding ratio had a shaker system, while those ranking 7, 8 and 10 used a chain drag. The mill ranking 9th used a chute and gravity feed.

TABLE 7—Comparison of grinding to feeding ratio with holding bin and feeding system

Rank (high to low)	Mill	Ratio (a)	Holding bin(s)	Feeding system
1	8	1.87	Large	Shaker—elevator leg
2	10	1.58	Large	Shaker—14" auger
3	2	1.50	Large	Shaker—elevator leg
4	6	1.39	Large	Shaker—elevator leg
5	5	1.27	Large bins—option of direct flow to grinder	Shaker—leg or direct
6	1	1.14	Medium size	Shaker—elevator leg
7	9	1.14	Through weigh bin	Chain drag—elevator leg
8	4	1.01	None (Held in pit—flow is controlled automatically.)	Chain drag—direct feed
9	7	1.00	None (Receiving chute serves as bin.)	Receiving chute
10	3	.88	Small—shuts off automatically when full. Manual restart	Chain drag—elevator leg

(a) Grinding time divided by feeding time. A high ratio indicates fast feeding relative to grinding.

Bagging and Loading

This is the final step in handling a grist. The two activities—bagging and loading the bags on the customer's carrier—were studied as one because the workers normally perform them as one. Timing for this job started when a mill employee obtained the first empty bag and continued until the last bag was loaded on the customer's carrier. Table 8 gives the average grist sizes, bagging and loading time, and the rank from low to high times among the sample mills.

Several things caused variation in loading time. These included

tying of bags, amount of customer help, and the ease of movement from the bagging to the loading area. The mills are ranked at the bottom of Table 8 from low to high in amount of employee, customer and total time required. Mill No. 10 ranked first in both employee and total time required. This mill had high average grist size, was very low in percent of bags tied, and ranked high in amount of customer help supplied.

Mill No. 4 ranked last in employee time and ninth in total time. This mill had above average size grists, tied 100 percent of the bags, and had a comparatively small amount of help from customers. These factors in mills 10 and 4 bring out the fact that bagging and loading time is low when bags are not tied and customers assist in loading. Customer help, however, is not equivalent to employee help. Also, in the mill having lowest time requirements, the bagging area was very conveniently located with respect to doorway and dock area, while the contrary was true in the mill with high time requirement.

Mill Integration

The time requirements indicated for various mill operations in the foregoing sections have two uses: (1) to indicate reasons for

Table 8—Average grist sizes and bagging and loading times

Mill number	1	2	3	4	5	6	7	8	9	10	Average
Average grist size											
Pounds	1388	1798	1579	1845	1770	1261	1206	1720	1823	2995	1739
Number of bags	15.6	22.5	16.8	21.9	20.0	16.1	13.9	19.4	20.8	32.7	20.0
Average elapsed time per grist (min.)	4.34	8.20	5.53	8.33	6.68	4.81	6.00	6.35	9.09	10.21	6.95
Percent of bags tied	25	36	19	100	52	32	38	84	43	4	43
Average time per bag (min.)											
Employee	.44	.48	.57	.74	.50	.39	.74	.60	.63	.32	.54
Customer	.23	.38	.36	.21	.32	.34	.28	.16	.26	.43	.30
Total	.67	.86	.93	.95	.82	.73	1.02	.76	.90	.75	.84
Average time per hundredweight (min.)											
Employee	.51	.60	.61	.87	.57	.50	.85	.67	.71	.33	.62
Customer	.31	.47	.39	.24	.31	.43	.32	.18	.28	.46	.34
Total	.82	1.07	1.00	1.11	.88	.93	1.17	.85	.99	.79	.96
Average time per hundredweight (rank from low to high)											
Employee	3	5	6	10	4	2	9	7	8	1	
Customer	4	10	7	2	5	8	6	1	3	9	
Total	2	8	7	9	4	5	10	3	6	1	

time requirement variations and (2) to assist in planning mills for a smooth flow of grist through the mill by means of proper integration of facilities.

Grinding capacity is the key to requirements in other mill operations. Therefore, it is necessary to first determine present mill grinding capacity or, when altering mill facilities, desired grinding capacity. The output per horsepower minute of the mills ranking from 1 to 5 in Table 6 is 1.30 pounds. The corresponding output of mills ranking from 6 to 10 is 1.16 pounds, but if we eliminate the mill ranked eighth the output is 1.24 pounds per horsepower minute. For illustrative purposes, we will consider grinding capacity to be 1.25 pounds per horsepower minute of hammermill, crusher, and blower. Time requirements for grinding feed with representative grinding horsepower and grist sizes are shown in Table 9.

TABLE 9—Grinding times with assumed grinding power and grist sizes

Grist size (pounds)	Hammermill, crusher, and blower horsepower		
	60	80	100
	Grinding time—minutes		
1000	13	10	8
2000	27	20	16
4000	53	40	32

To keep the grinder operating at all times, it is necessary that the mill have feeding capacity in excess of grinding capacity and a holding bin to keep the grinder operating while the succeeding vehicle is positioning and preparing to unload. The amount of extra feeding and holding bin capacity needed would vary with each situation. Consider, for instance, a mill having a 100-horsepower grinder where it is considered desirable to be prepared to receive tractor and trailer carriers without grinding delay. Average tractor and trailer positioning time is .77 minute and average preparation time at all mills is .58 minute, a total of 1.35.

This means only that approximately half of the tractor and trailer carriers would be positioned and prepared to unload in 1.35 minutes or less and that half would require more time. It is, however, a guide to time requirements. A 100-horsepower grinder would grind about 170 pounds of grist in this time. If it is desired to accumulate

sufficient grain in the holding bin to cover average positioning and preparation time for the following grist, it is necessary that the feeding rate be greater than the grinding rate.

For grists of 1,000 pounds, a grinding feeding ratio of about 1.2 should be supplied, i.e., feeding rate should exceed grinding rate by about 20 percent. Of course, there is the possibility that unloading will be completed and the receiving area cleared in sufficient time to allow positioning and preparation while feeding and grinding of the previous grist are continuing. However, experience seems to indicate that the receiving area is vacated more rapidly when the receiving pit is emptied rapidly.

Size and number of mixers required depend upon size of grists to be handled, grinding speed, and bagging and loading speed. If all grists were of equal size, it would be necessary only to have two mixers of sufficient size to handle the grists, and bagging and loading speed sufficiently greater than grinding speed to take care of additives. However, grists are not equal in size, so the mill operator must decide how much variation he should be able to handle. For instance, if most of the grists fall between 1,000 and 4,000 pounds, two 2-ton mixers should suffice and sufficient labor should be supplied to bag and load 4,000 pounds while 1,000 pounds are being ground.

The advantages of being prepared for extreme variations such as this must, however, be weighed against the necessity of having excess labor available at other times. One thousand pounds of grain can be ground in about 8 minutes. An average of nearly 25 minutes of employee time plus 14 minutes of customer time was required to bag and load 4,000 pounds of feed.

If no wait is to be allowed, a total of three employees and two customers would be required for bagging and loading. Without customer help, five employees would be required. Then, if a 4,000-pound grist followed one of 1,000 pounds of feed, 32 minutes of grinding time would be required—a total of 96 man minutes for three employees. Since only about 6 man minutes of employee time would be needed for bagging and loading, 90 man minutes of excess employee time would result. While some of the excess labor could be utilized for other tasks, much likely would be wasted.

If extreme variation in grist size is prevalent, it may be less expensive to even out the bagging and loading rate requirement by

installing a third mixer. It would then be necessary to supply sufficient labor for average conditions with the third mixer used to smooth an exceptionally uneven flow.

Summary

The time requirements of each operation in 10 feed mills have been presented and compared. From these time requirements, it can be seen that there are many things affecting feed mill efficiency. The mill operator can have control over nearly all of these, although there are some exceptions. He has no control over the type of vehicle his customers use to deliver grain to his mill, although this will come more under his control as custom hauling and the grain bank increase in importance.

The time savings of improvements in operations, such as positioning and preparation, have no apparent direct economic value to the mill operator when the job is performed by his customers. However, a customer may be won or lost as a result of the speed, or lack of speed, that can be attained in all grist handling operations.

Grinding speed was found to approximate 1.25 pounds per horsepower minute of hammermill, crusher, and blower. This, of course, varies with the kind and condition of grain and fineness of grind.

Mixing is a mechanical operation and was not covered in this report. Bagging and loading was found to vary with percent of bags tied, amount of customer help supplied, and the ease of movement from the bagging to the loading area.

Integration of the various operations revolves around the grinding rate. Since grist size and composition and importance of customer convenience and service vary among mills, it is not possible to state universally applicable rules for integration of mill operations. However, general rules for determination of needed rates in each operation have been given.

A RAPID METHOD OF OBTAINING TREE WEIGHT DATA ON ORCHARD TREES

By WALTER TOENJES

DEPARTMENT OF HORTICULTURE

IN COLLECTING RESEARCH DATA on fruit trees, frequently it is desirable to obtain the weights of the above-ground parts of the trees at the conclusion of an experiment. However, when a large number of trees are involved, the anticipated amount of labor required to obtain these data may be a deterrent. This is especially true when the value of the data may not appear at the time to justify the effort and expense of dismembering each tree and weighing the individual portions, a common procedure in the past.

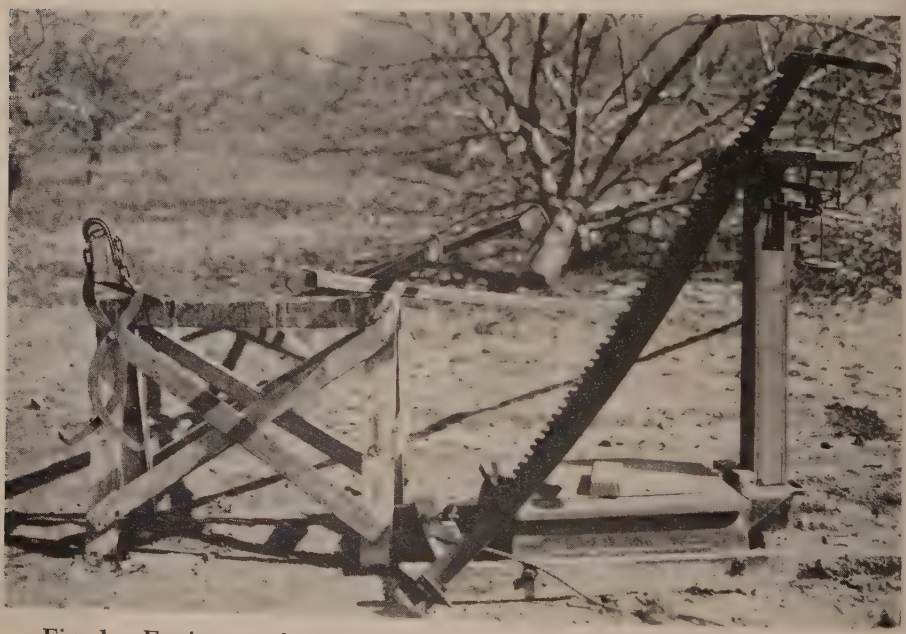

Fig. 1. Equipment, left to right, saw horse, well braced; oak lifting pole equipped with clevis and heavy ice tongs; three bracing poles with locking hooks; crosscut saw; and platform scales on skids.

ARTICLE 43-8

Fig. 2. The three 16-foot brace poles are hooked around branches near the center tops of the trees, in a triangular position. Two of the three men holding the poles push toward the third pole to relieve the pinching of the saw while the tree is being sawed off.

A more simple and rapid method of obtaining these tree weights was developed at the Michigan State University Graham Experiment Station, Grand Rapids, when such data were highly desirable at the termination of a pruning experiment. One hundred 14-year-old apple trees, ranging from 18 to 30 inches in trunk circumference, were sawed off at the ground line and weighed in 18 hours by a crew of five men. Individual tree weights ranged between 350 and 700 pounds. With a little experience a tree could be sawed off and weighed in from five to 10 minutes depending upon its size.

The equipment used for the work, as shown in Fig. 1, is comparatively simple, inexpensive, and efficient. The saw horse, bracing poles, and lifting pole with ice tongs, are easy to make and assemble. A cross-cut or chain saw and platform scales are always readily available.

The height of the saw horse should be from 26 to 30 inches, and

well braced. If higher, it may be difficult to place close to the trunk of a tree having low-hanging branches. The 10-foot hardwood lifting pole is equipped with a clevis and ice tongs on one end, with two shallow notches cut on its bottom edge to prevent slippage on the saw horse, Fig. 3. The length of the chain connecting the upper ends of the tongs should be sufficiently long to permit adequate spreading of the tong points to accommodate the largest tree trunks involved. The three bracing poles are made of good straight-grained wood, two by two inches square, and 16 feet long. The locking hooks mounted on the ends of the bracing poles are made of ⅜- or ½-inch iron rods and are held in place with either eye bolts or U bolts. The upward-bent portion on the lower end of the hook rod, prevents the hook from revolving more than one-half turn on the brace pole, Fig. 1. A quarter turn of the brace pole puts the hook in either the open or the locked position. When

Fig. 3. After the tree is sawed off the fourth man moves the saw horse close to the tree trunk. He then places the lifting pole over it and hooks the points of the ice tongs into the trunk near the base. Downward pressure on the lifting pole forces the points of the tongs into the trunk enabling it to be lifted. The fifth man pulls the scales under the raised tree which is then lowered onto the scale platform and weighed.

Fig. 4. After weighing the tree again is raised and the scales pulled away. It is then lowered onto the stump, the brace poles unlocked and removed, and the tree allowed to fall over.

open, the hook is placed around a sturdy branch near the center top of the tree and locked by turning the brace pole. The wheels on the 1000-pound capacity platform scale were replaced by 2″ x 4″ skids. A short pull-rope aids in moving the scale into position, and from tree to tree.

As previously stated, a crew of five men proved adequate and most efficient for using this equipment. The legends accompanying Figs. 1, 2, 3, and 4 aid in describing the procedure of operation as well as illustrating the design of the equipment.

MICHIGAN FARM BUSINESS REPORT FOR 1959

By CHARLES BEER[1]

AGRICULTURAL ECONOMICS DEPARTMENT

THE EARNINGS of a sample of Michigan farmers are down considerably in 1959 from the previous year (Table 1). Eight of the 10 areas for which reports are prepared showed a decrease in labor earnings. Area 8 and 9-12-14 show a small increase over the 1958 figures. (Table 4 and Table 6).

This information was obtained from the farm records of 887 farmers throughout the state. These accounts were kept as part of the Cooperative Extension Service Program in each county. The records were summarized under the supervision of farm management specialists in the Agricultural Economics Department at Michigan State University.

FARM EARNINGS

The earnings, shown as labor income, are presented in Table 1. These figures cover a 31-year period, the length of time this project has been operating in Michigan. Labor income, as shown here, is the return to the farm operator for his labor and management. It is calculated by deducting from the gross income all cash operating expenses, depreciation, family labor (other than operator), and 5 percent interest on the investment in the farm operation.

Another way of showing the financial condition of farmers is by classifying them into earning groups. In such a breakdown, (Table 2) 26 percent of the 887 farmers went into the "red" in 1959. That is, they had a labor earning of zero or less. Twelve percent had labor incomes between $1 to $1,000 and 62 percent were above $1,000.

[1] Co-workers on this project are J. Doneth, L. Brown, E. Elwood, L. Kyle, M. Kelsey, W. Vincent, and R. Wheeler. Appreciation is also expressed to the county extension agents and to the cooperating farmers for their contributions which provided the data for this article.

ARTICLE 43-9

TABLE 1—Earnings on farm accounting farms in Michigan by years, 1929-1959, and 31-year average

Year	Labor income	Year	Labor income
1929.....	$585	1945.....	$2,483
1930.....	−263	1946.....	3,374
1931.....	−676	1947.....	3,486
1932.....	−595	1948.....	2,735
1933.....	249	1949.....	1,815
1934.....	565	1950.....	2,688
1935.....	764	1951.....	3,782
1936.....	1,318	1952.....	2,926
1937.....	569	1953.....	2,447
1938.....	571	1954.....	1,755
1939.....	780	1955.....	993
1940.....	787	1956.....	2,646
1941.....	1,675	1957.....	2,360
1942.....	2,303	1958.....	3,426
1943.....	1,900	1959.....	2,049
1944.....	2,406		
31-year average, 1929-1959.....			$1,674

These figures reveal, in a general way, what is taking place on Michigan farms, but they do not represent the average farmer as shown by the census reports. The farmers keeping accounts in this project generally have larger farms than the average of all Michigan farms. As a group, they are considered better than average operators. All the farmers used a standardized bookkeeping procedure and had their farm business records summarized at the university. The sample of farms changes slightly from year to year. Therefore, the earning figures between various years may not be entirely comparable.

The charge for family labor, the inventory values for feed and crops and for non-breeding livestock are changed each year in an attempt to keep data in line with current conditions. Relatively fixed values are used for land, improvements, and breeding stock. Land values were adjusted upward in 1959 to reflect more closely the current market value.

Actually, the decrease in 1959 farm earnings is not as severe as these figures indicate. Only about one-third of the $1,377 decline in labor income was due to a poorer income-expense relationship. Two-thirds of the drop resulted from additional interest charged to

investment. The land investment was increased almost 60 percent because of revision of land values.

One other observation is important, but not apparent from these figures. These earning figures represent only the results from farm operation. The figures do not include the increase in value of farm real estate, which in some areas has been considerable.

TABLE 2—Percentage and distribution of labor incomes, 1929-1959

Period	Total number of farms	Farms in each labor income group		
		$0 or less	$1 to $1,000	$1,000 and over
		Percent	Percent	Percent
1929-33, 5 year average	750	58	33	9
1934-38, 5 year average	1,050	16	53	31
1939	1,346	14	54	32
1940	1,263	12	55	33
1941	1,041	5	27	68
1942	1,160	2	18	80
1943	1,097	8	24	68
1944	1,031	5	18	77
1945	939	6	17	77
1946	838	4	9	87
1947	830	5	11	84
1948	846	8	15	77
1949	912	9	16	75
1950	826	11	17	72
1951	685	7	9	84
1952	551	13	11	76
1953	501	20	14	66
1954	545	25	18	57
1955	539	34	17	49
1956	526	17	11	72
1957	881	22	12	66
1958	862	15	8	77
1959	887	26	12	62

FINANCIAL SUMMARY

Gross income has increased steadily since 1955 to a high of $18,657 in 1959. Expenses have also increased and at a more rapid rate. Comparing 1959 with 1958, the expenses increased by 7 percent ($907) while gross income increased by 2 percent ($374). This resulted in a 9 percent decrease in net farm income. The interest charge on investment increased by 32 percent and this left a labor income of $2,049, down 40 percent from 1958.

A different way of showing returns to farmers is to include in costs a charge for operator's labor instead of the charge for interest on investment. After such charge has been made (see bottom of Table 3), the net is shown as a percent of the total investment figure, thus giving the rate earned on capital invested in the farm business. On these farm account farms, the rate earned on capital investment has averaged about 5 percent over the last several years.

The financial summary on a cash basis is shown in Table 4. Cash

TABLE 3—Comparison of gross income, expenses, and labor income on accounting farms in Michigan

Item	1954	1955	1956	1957	1958	1959
Income:						
Crops	$3,643	$2,521	$3,600	$2,814	$3,956	$3,956
Dairy products	4,994	5,476	6,840	8,198	8,247	9,212
Cattle	1,438	1,514	1,745	1,621	2,988	2,921
Hogs	1,049	620	903	1,093	1,320	867
Poultry and eggs	946	1,125	868	729	782	708
Sheep	131	100	119	116	102	102
Other	698	737	780	954	888	891
Gross income	$12,899	$12,093	$14,855	$15,525	$18,283	$18,657
Expenses:						
Feed	$1,832	$1,655	$1,863	$1,820	$2,209	$2,184
Machinery	2,707	2,889	3,201	3,479	3,698	3,959
Hired labor	1,011	886	1,024	850	1,019	1,168
Family labor	619	639	672	700	734	885
Crop expense	1,523	1,490	1,554	1,591	1,971	2,138
Improvements	764	768	842	1,028	1,178	1,225
Taxes	273	317	391	432	513	566
Other	562	578	639	787	882	986
Total Expenses	$9,291	$9,222	$10,186	$10,687	$12,204	$13,111
Net farm income	$3,608	$2,871	$4,669	$4,838	$6,079	$5,546
Interest on investment at 5%	1,853	1,878	2,023	2,478	2,653	3,497
Labor income	$1,755	$993	$2,646	$2,360	$3,426	$2,049
Investment	$37,060	$37,560	$40,460	$49,560	$53,060	$69,940
Net farm income	$3,608	$2,871	$4,669	$4,838	$6,079	$5,546
Operator's labor charge	2,044	2,050	2,049	2,070	2,065	2,477
Return on investment	$1,564	$ 821	$2,620	$2,768	$4,014	$3,069
Rate earned on investment	4.2%	2.2%	6.5%	5.6%	7.6%	4.4%

TABLE 4—Cash summary for all Michigan accounting farms and for various areas for 1959

Item	All farms	Type-of-farming area (*a*)									
		1	2	3 and 11(*b*)	4	5	6-7	8	9-12-14	10	15-16-17
Cash income											
Crop sales	$ 3,713	$ 4,370	$ 3,333	$12,531	$ 1,915	$ 3,854	$ 2,967	$10,204	$ 1,108	$ 4,109	$ 1,258
Dairy products	9,212	8,047	7,734	4,660	9,618	11,174	12,100	6,485	7,178	8,656	7,548
Dairy cattle	1,996	1,969	1,914	2,674	2,032	2,299	2,153	1,498	2,038	2,154	1,355
Beef	1,855	6,293	2,237	....	1,388	1,822	1,629	2,558	617	966	36
Eggs	722	912	1,181	369	2,326	597	662	238	539	531	344
Poultry meat	100	63	324		483	64	26	18	50	53	17
Hogs	1,117	2,453	3,635	312	836	1,213	362	718	173	653	17
Sheep and wool	135	298	273		48	192	19	59	135	100	22
Custom work	225	292	162	119	109	234	172	455	198	235	150
Labor off farm	262	348	394	215	212	163	227	219	373	349	245
Machinery sales	86	88	80	....	73	110	25	163	51	134	35
Improvement sales	8	22	9	....	....	10	10	10	....	7	5
Other sources	405	340	337	417	335	395	400	492	395	452	486
Total	$19,836	$25,495	$21,613	$21,297	$19,375	$22,127	$20,752	$23,117	$12,855	$18,399	$11,518
Cash expenses and depreciation											
Hired labor	$ 1,168	$ 1,365	$ 1,013	$ 4,726	$ 1,033	$ 1,298	$ 1,164	$ 1,455	$ 644	$ 1,617	$ 805
Feed purchased	2,184	3,039	3,175	839	3,585	2,190	1,923	1,481	1,719	1,871	1,371
Crop expense	1,908	2,474	1,897	3,428	1,416	2,152	1,995	2,900	941	2,082	867
Custom hire	230	327	276	160	211	251	227	350	133	160	98
Machinery: Cash operating expense	2,000	2,335	1,800	1,983	1,624	2,251	2,202	2,383	1,421	2,085	1,386
Depreciation	1,947	1,917	1,790	1,813	1,730	2,196	2,161	2,464	1,410	2,022	1,409
Net new investments	779	979	729	....	305	1,125	760	796	376	924	213
Improvements: Cash operating expenses	500	555	524	445	560	553	577	523	326	463	341
Depreciation	726	821	682	492	663	866	791	1,048	403	536	445
Net new investments	538	1,144	376	....	53	799	444	959	81	362	192
Livestock bought: Dairy cattle	631	958	773		490	867	388	389	756	489	225
Beef Cattle	1,189	4,227	1,611		924	1,286	1,105	1,202	51	683	2
Hogs	102	303	228	1,123	108	88	12	84	24	179	2
Sheep	28	43	97		....	33	13	4	15	17	7
Poultry	107	170	217		249	103	84	23	120	34	25
Livestock expense	589	661	700	313	559	708	736	426	404	451	371
Taxes	566	688	570	454	530	704	685	666	305	440	233
Other	397	390	376	401	398	425	462	400	309	413	340
Total	$15,589	$22,396	$16,834	$16,177	$14,438	$17,895	$15,729	$17,553	$ 9,438	$14,828	$ 8,332

(*a*) See Figure 1.
(*b*) Includes only the diversified fruit farms

TABLE 4—(Concluded)

Item	All farms	Type-of-farming area (a)									
		1	2	3 and 11(b)	4	5	6-7	8	9-12-14	10	15-16-17
Inventory changes											
Farm improvements	$ 529	$ 1,122	$ 366	....	$ 53	$ 785	$ 435	$ 947	$ 81	$ 354	$ 189
Machinery	681	891	650	....	231	1,015	734	633	325	791	178
Feed and crops	243	−583	−776	- 431	−137	490	206	910	467	879	185
Dairy cattle	698	731	734		672	954	883	354	640	414	334
Beef cattle	192	457	422		89	285	217	85	−7	8	−22
Hogs	−148	−287	−574	- 302	−151	−176	28	−144	−5	−11	−5
Sheep	−6	−18	−14		....	−13	20	−5	−19	−4	6
Poultry	−5	15	4		−58	−15	44	−23	12	−37	−15
Other	....	....	....		....	....	−2	....	....	....	2
Net inventory change	$ 2,184	$ 2,328	$ 812	$ −733	$ 699	$ 3,325	$ 2,565	$ 2,757	$ 1,494	$ 2,394	$ 852
Summary											
Net financial balance	$ 4,247	$ 3,099	$ 4,779	$ 5,120	$ 4,937	$ 4,232	$ 5,023	$ 5,564	$ 3,417	$ 3,571	$ 3,186
Inventory increase	2,184	2,328	812	−733	699	3,325	2,565	2,757	1,494	2,394	852
Net income	6,431	5,427	5,591	4,387	5,636	7,557	7,588	8,321	4,911	5,965	4,038
Family labor	885	1,126	721	950	867	898	980	889	904	775	791
Net farm income	5,546	4,301	4,870	3,437	4,769	6,659	6,608	7,432	4,007	5,190	3,247
Interest on investment @ 5%	3,497	4,215	3,612	3,095	3,524	3,981	3,903	4,503	2,370	2,734	1,735
Labor income	2,049	86	1,258	342	1,245	2,678	2,705	2,929	1,637	2,456	1,512

(a) See Figure 1.
(b) Includes only the diversified fruit farms.

income, inventory changes, and an earnings summary are shown for all account farms and also for each of the type-of-farming areas in the state.

Physical changes which occurred on these sample farms are shown in Table 5. The increase in acreage, both total and tillable, continues. The amount of livestock and work load are well above the 1954 figures, but are down slightly from 1958.

TABLE 5—Comparison of size of farm and amount of work, on Michigan farm account farms, 1954-1959

Item	1954	1955	1956	1957	1958	1959
Number of farms	545	539	526	881	862	887
Total acres	230	234	245	259	263	270
Tillable acres	166	167	178	188	194	200
Animal units	37.5	38.0	39.7	42.5	54.0	49.0
Man-work units	409	411	451	465	546	541
Number of men	1.7	1.7	1.6	1.6	1.7	1.7
Work units per man	243	258	271	290	320	309

TYPE-OF-FARMING AREA INFORMATION

The previous figures and information are an average of all account farms throughout the state, exclusive of specialized fruit farms in the 1957, 1958 and 1959 figures[2]. Tables 6, 7, 8, and 9 present information for the type-of-farming districts in the state. Some areas have been combined so that the data is presented by districts rather than individual type-of-farm areas. Fig. 1 shows the type of farming areas in Michigan.

The data presented includes a financial summary; the kind of crops grown, crop yields and percent of land in each crop; the kind, amount and return of livestock; and the various expenses and their relationship to each other.

[2] For details on the specialized fruit farms the author suggests the use of the Area 3-11 report, A. Ec. 779, 1960, published by the department of agricultural economics, Mich. State. Univ.

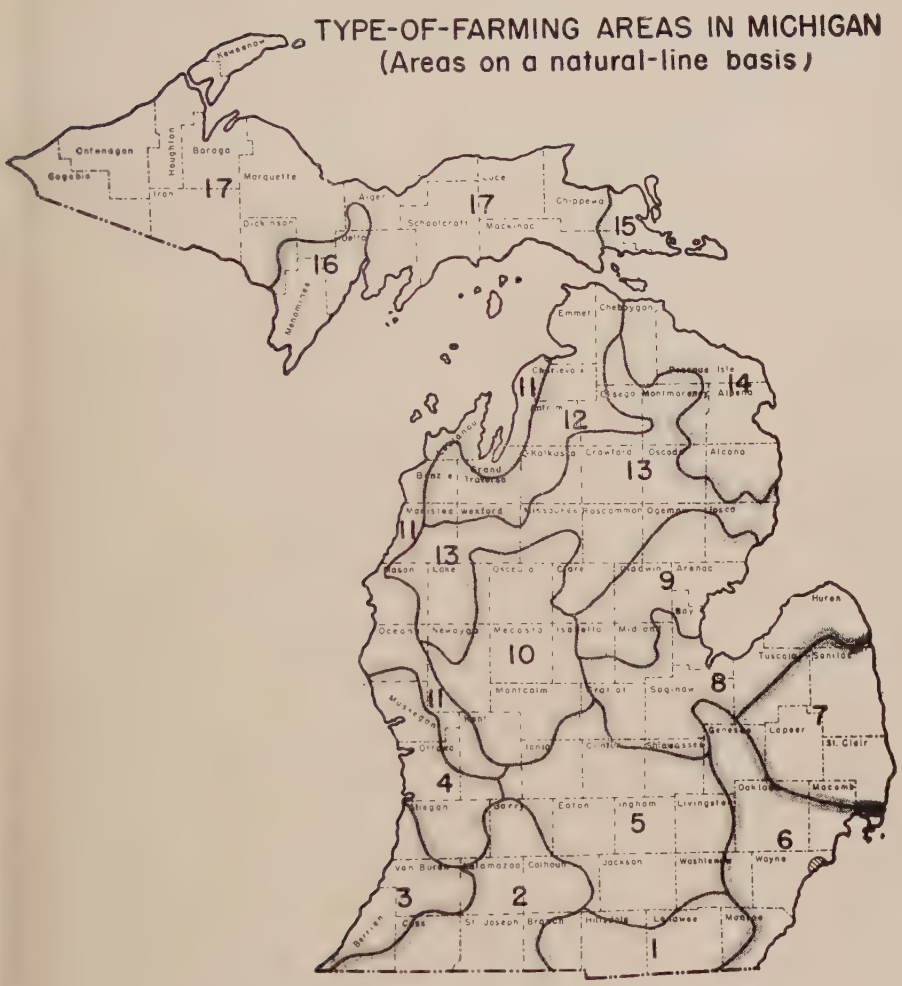

Fig. 1. Type-of-farming areas in Michigan.

TABLE 6—Financial summary of 887 Michigan account farms by type-of-farming area, 1959

Item	All farms	Type-of-farming area									
		1	2	3-11	4	5	6-7	8	9-12-14	10	15-16-17
Number of farms	887	65	95	17	51	227	119	85	91	72	82
Total acres	270	252	254	208	209	290	265	243	297	262	302
Percent of farm acres tillable	74	...	...	...	...	...	...	...	...	...	...
Tillable acres	200	203	203	159	173	228	217	198	173	182	156
Real estate (less house (*a*))	$46,466	$56,693	$48,592	$42,569	$48,346	$52,345	$51,809	$65,506	$31,189	$33,506	$19,303
Machinery and equipment	9,232	9,134	8,596	8,305	8,688	10,091	10,449	10,644	7,181	9,181	7,100
Livestock (*a*)	9,021	11,431	5,873	5,611	9,109	10,889	10,211	7,138	6,610	7,762	5,699
Feed and crops	5,237	7,012	9,178	5,409	4,428	6,236	5,679	6,814	2,426	4,197	2,588
Capital investments (*a*)	$69,956	$84,270	$72,239	$61,894	$70,571	$79,561	$78,148	$90,102	$47,406	$54,646	$34,690
Livestock income	$13,810	$15,233	$14,943	$ 7,713	$15,512	$16,018	$16,542	$10,137	$10,384	$12,080	$ 9,377
Crop income	3,956	3,787	2,557	12,100	1,779	4,344	3,173	11,114	1,575	4,988	1,444
Other income	891	980	893	751	656	792	795	1,166	966	1,036	881
Gross income	$18,657	$20,000	$18,393	$20,564	$17,947	$21,154	$20,510	$22,417	$12,925	$18,104	$11,702
Total expense (*b*)	13,111	15,699	13,523	16,177	13,178	14,495	13,902	14,985	8,918	12,914	8,455
Net farm income	$5,546	$4,301	$4,870	$4,387	$4,769	$6,659	$6,608	$7,432	$4,007	$5,190	$3,247
Less interest at 5%	3,497	4,215	3,612	3,095	3,524	3,981	3,903	4,503	2,370	2,734	1,735
Labor income 1959	$2,049	$ 86	$1,258	$ 342	$1,245	$2,678	$2,705	$2,929	$1,637	$2,456	$1,512
Labor income 1958	3,426	5,431	4,730	2,875	3,004	4,237	3,166	2,847	1,548	2,672	1,603
Labor income 1957	2,360	2,353	3,433	2,880	2,357	2,477	1,927	2,747	1,783	3,008	1,348
Labor income 1956	2,646	2,690	3,380	1,468	2,244	3,075	2,938	3,756	2,180	2,089	1,163
Labor income 1955	993	1,420	387	1,528	−126	729	1,198	2,752	886	652	841
Labor income 1954	1,755	3,079	1,172	3,080	917	2,451	786	2,238	916	918	588
Labor income 1953	2,447	3,283	2,142	5,402	1,914	2,999	1,542	3,403	1,296	1,537	916
Labor income 1952	2,926	2,984	2,916	3,860	2,930	3,589	3,103	3,742	1,826	2,485	1,797
Labor income 1951	3,782	4,533	4,845	2,765	3,752	5,173	3,633	4,726	2,309	3,233	1,888
Labor income 1950	2,688	3,389	3,309	3,239	2,885	3,687	2,041	4,057	1,148	2,300	1,364
Labor income, 10 year average	2,507	2,925	2,757	2,744	2,112	3,110	2,304	3,045	1,553	2,135	1,302

(*a*) Investment figures tend to represent long time account book and not current valuations.
(*b*) Includes family labor but not operator's labor or interest on investment.

TABLE 7—Kinds of crops, percentage of tillable land in different crops, and yields on farm accounting farms: by type-of-farming areas in Michigan, 1959

Item	All farms	Type-of-farming area									
		1	2	3 and 11	4	5	6 and 7	8	9-12-14	10	15-16-17
Number of farms	887	65	95	..	51	227	119	85	91	72	82
Number of tillable acres	..	203	203	..	173	228	217	198	173	182	156
Percent in sod crops	..	28	36	..	42	..	42	24	64	47	65
Percent tillable acres in:											
Tillable pasture	13	8	12	..	12	12	13	8	21	14	19
Alfalfa hay	19	14	19	..	19	20	20	14	21	23	10
Other hay	8	5	4	..	8	3	8	1	17	8	35
Grass silage	2	1	1	..	3	1	1	1	5	2	1
Corn (includes silage)	27	44	32	..	30	33	27	21	13	21	3
Wheat	10	9	13	..	12	12	10	13	4	7	1
Oats (oat mixtures)	11	10	11	..	10	9	10	9	12	10	21
Barley	1	..	2	..	1	1	1	1	1	1	..
Field beans	3	..	..	..	..	1	4	19	..	1	..
Soybeans	..	3	..	..	..	..	..	..	..	..	..
Sugar Beets	..	..	..	..	..	..	..	8	..	..	..
Potatoes	..	..	..	..	..	..	..	..	1	..	2
Fruit and truck	..	..	..	..	..	..	..	..	..	..	..
Other	2	3	3	..	2	4	2	3	1	8	4
Idle	4	3	3	..	3	4	4	2	4	5	4
Crop yield per acre:											
Alfalfa hay, ton	3.1	2.8	2.9	..	3.0	3.3	3.3	3.3	2.3	2.7	2.7
Other hay, ton	2.1	2.9	1.9	..	2.1	2.4	2.6	2.6	1.8	2.2	1.9
Corn, shelled, bu	67	71	60	..	58	69	68	79	58	63	..
Wheat, bu	35	30	34	..	30	37	35	42	31	31	25
Oats, bu	47	49	41	..	36	53	66	72	34	30	35
Barley, bu	39	..	41	..	24	42	47	60	19	37	..
Beans, bu	27	..	..	..	..	20	16	25	..	20	..
Sugar beets, ton	..	..	..	..	..	..	..	..	..	..	..
Potatoes, bu	..	..	..	..	..	..	..	..	314	..	378
Soybeans, bu	..	40	..	..	..	..	..	..	..	..	..
Crop value per tillable acre	$ 55	$ 59	$ 49	..	$ 49	$ 57	$ 55	$ 79	$ 37	$ 58	$ 38
Crop sales and ASC pay's	3,713	4,370	3,333	..	1,915	3,854	2,967	10,204	1,108	4,109	1,258
Crop income total	3,956	3,787	2,557	..	1,779	4,344	3,173	11,114	1,575	4,988	1,444
Feed bought	2,184	3,039	3,175	..	3,585	2,190	1,923	1,481	1,719	1,871	1,371
Fertilizer per tillable acre	$ 6.54	$ 8.14	$ 6.99	..	$ 5.98	$ 6.70	$ 6.41	$10.14	$ 3.46	$ 6.62	$ 3.13

TABLE 8—Livestock: kinds, amounts, and returns from livestock, by type-of-farming areas on farm accounting farms in Michigan, 1959

Item	All farms	Type-of-farming area									
		1	2	3 and 11	4	5	6 and 7	8	9-12-14	10	15-16-17
Number of farms	887	65	95	..	51	227	119	85	91	72	82
Livestock income total	$13,810	$15,233	$14,943	..	$15,512	$16,018	$16,542	$10,137	$10,384	$12,080	$9,375
Livestock income per tillable acre (*a*)	69.05	75.09	73.72	..	89.93	70.60	76.35	51.10	59.88	66.40	60.13
Productive animal units	49.0	61.5	63.2	..	47.2	55.2	50.3	35.5	39.8	42.9	33.9
Tillable acre per P.A.U. (*b*)	4.1	3.3	3.2	..	3.7	4.1	4.3	8.7	4.4	4.2	4.6
Cattle:											
Percent farms reporting	88	82	83	..	92	90	94	66	96	88	99
Dairy cows per farm	27.3	26.0	23.6	..	26.7	31.5	31.6	23.4	21.4	27.2	24.5
Dairy product sales per cow	382	379	393	..	390	393	406	421	351	363	312
Dairy sales on farms reporting	10,436	9,869	9,300	..	10,437	12,373	12,857	9,844	7,509	9,893	7,641
Income/farms reporting	7,443	11,250	7,238	..	5,928	7,295	7,991	8,660	2,480	4,275	2,441
Hogs:											
Percent farms reporting	34	55	66	..	35	43	14	31	31	17	6
Sows per farm	10.4	13.3	16.3	..	8.3	8.4	11.2	5.6	4.8	4.9	12.0
Litters farrowed/farm	12.7	26.0	28.4	..	6.4	15.8	21.9	10.5	7.9	9.8	12.0
Pigs weaned/litter	7.0	7.3	7.0	..	6.1	6.8	8.0	7.1	6.2	6.8	8.2
Hog income per litter	168	175	187	..	160	167	210	242	69	222	83
Income/farms reporting	2,592	3,365	4,534	..	1,638	2,197	2,647	1,603	468	2,778	160
Sheep:											
Percent farms reporting	10	12	15	..	6	15	6	6	11	..	5
Ewes per farm	46	89	46	..	36	41	31	48	49	..	19
Lambs raised/100 ewes	101	98	99	..	93	107	85	90	111	..	103
Sheep income per ewe	22	27	13	..	26	24	16	18	19	..	35
Income/farms reporting	1,052	1,924	1,095	..	819	978	442	855	923	..	434
Poultry:											
Percent farms reporting	38	43	39	..	51	40	38	34	37	29	33
Hens/farm reporting	357	458	492	..	833	340	349	174	272	306	184
Egg sales per hen	$5.31	$4.62	$6.16	..	$5.46	$4.38	$7.03	$4.00	$5.30	$5.95	$5.68
Egg sales/farm reporting	1,894	2,118	3,033	..	4,562	1,490	1,749	698	1,442	1,820	1,045
Meat income per farm reporting	−88	−218	280	..	−344	−137	−35	−82	−159	−62	−71

(*a*) Tillable acre.
(*b*) Productive animal unit.

by type-of-farming areas in Michigan, 1959

Item	All farms	Type-of-farming area									
		1	2	3 and 11	4	5	6 and 7	8	9-12-14	10	15-16-17
Number of farms	887	65	95	..	51	227	119	85	91	72	82
Gross income per tillable acre	$ 93.34	98.59	90.69	....	103.99	92.78	94.66	113.00	74.68	99.51	75.05
Total expense per tillable acre (*a*)	$ 77.92	90.17	79.31	....	91.88	74.93	76.15	88.33	64.43	82.91	68.13
Total expenses (*a*)	$15,588	18,287	16,083	....	15,856	17,085	16,496	17,523	11,149	15,081	10,624
Man labor:											
Number of men	1.7	1.9	1.6	....	1.7	1.8	1.8	1.8	1.7	1.9	1.6
Income per man	$10,671	10,612	11,288	....	10,581	11,921	11,481	12,711	7,774	9,620	7,108
Days of work per man (*b*)	309	309	328	....	304	342	331	290	266	278	262
Hired labor	$ 1,168	1,365	1,013	....	1,033	1,298	1,164	1,455	644	1,617	805
Family labor	$ 885	1,126	721	....	867	898	980	889	904	775	791
Operator's labor	$ 2,477	2,588	2,560	....	2,678	2,590	2,594	2,538	2,231	2,167	2,169
Expense per tillable acre	$ 22.60	25.05	21.17	....	26.53	20.98	21.87	24.61	21.84	25.06	24.15
Power and machinery:											
Investments	$ 9,232	9,134	8,596	....	8,688	10,091	10,449	10,644	7,181	9,181	7,100
Income/$1,000 investment	$ 2,021	2,190	2,140	....	2,066	2,096	1,963	2,106	1,800	1,972	1,648
Annual expense	$ 3,959	4,253	3,589	....	3,357	4,447	4,363	4,846	2,831	4,105	2,795
Expense per tillable acre	$ 19.80	20.97	17.70	....	19.45	19.50	20.14	24.43	16.36	22.56	17.92
Improvements:											
Investment (less house)	$12,837	15,125	12,364	....	14,031	15,003	13,466	16,968	7,699	9,836	7,977
Investment per productive animal unit	$ 262	246	196	....	297	272	267	476	194	229	236
Annual expense	$ 1,225	1,377	1,206	....	1,222	1,421	1,368	1,572	729	1,000	784
Expense per tillable acre	$ 6.14	6.79	5.95	....	7.08	6.24	6.31	7.92	4.21	5.50	5.03
Feed bought	$ 2,184	3,039	3,175	....	3,585	2,190	1,923	1,481	1,719	1,871	1,371
Crop expense	$ 1,908	2,474	1,897	....	1,416	2,152	1,995	2,900	941	2,082	867
Custom hire	$ 230	327	276	....	211	251	227	350	133	160	98
Taxes (real estate)	$ 566	688	570	....	530	704	685	666	304	440	233
Other expenses	$ 986	1,050	1,076	....	957	1,134	1,197	826	713	864	711
Feed bought per tillable acre	$ 10.93	14.98	15.66	....	20.77	9.60	8.88	7.47	9.93	10.29	8.79
Crop expense/tillable acres (less custom)	$ 9.54	12.20	9.36	....	8.21	9.44	9.21	14.62	5.44	11.45	5.56
Custom work per tillable acre	$ 1.15	1.61	1.36	....	1.23	1.10	1.05	1.76	.77	.88	.63
Real estate taxes at tillable acre	$ 2.83	3.39	2.81	....	3.07	3.09	3.16	3.36	1.76	2.42	1.49
Other expenses per tillable acre	$ 4.93	5.18	5.30	....	5.54	4.98	5.53	4.16	4.12	4.75	4.56

(*a*) Includes operator's and family labor, but not interest on investment.
(*b*) Fruit farms excluded.

FACTORS AFFECTING THE ACTIVITY OF SPRAY-DRIED CHEESE CULTURE

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INTRODUCTION

The successful propagation of lactic culture organisms has been a serious problem in many dairy plants. Technical knowledge, technique and facilities must be adequate to maintain a good culture. Otherwise, poor quality cottage cheese and other cheeses may be traced to the culture that was used.

A means of economically providing a good, active culture should reduce the cottage cheese failures, improve the quality and relieve the plant personnel of a task requiring much care and skill. These are traits that are frequently not developed in the small dairy plants.

The fact has been known many years that bacteria may remain viable in a dry medium. More recently, lyophilization has been used as an effective means of dehydrating cultures. The system is too expensive to warrant its use for culture inoculation directly into the milk in the setting process for the commercial manufacture of cheese

The literature indicates that previous investigations involved principally the desiccation of small quantities of culture material for the purpose of maintaining viability for a long period of time. Stark and Herrington (1930) reported approximately 66 percent of the Streptococci were able to grow in a culture medium after 97 days under dry conditions. Rogers (1914) obtained varying degrees of success in preserving viability of bacteria by rapidly removing the water using a warm air current. Downs (1920), Macy (1928) and others have reported the survival of various types of bacteria in dry milks.

Relative humidity changes from 80 to 10 percent were shown by

[1] Partially supported by the Dairy Industries Supply Association Fellowship.

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Higgenbottom (1953) to improve the survival of microorganisms in dry milk. The loss of viability was more rapid with a high moisture content of dry milk according to Rogers (1914) and Proom and Hemmons (1949). Rogers also observed a deleterious effect of oxygen on bacteria in dry milk during storage. Vacuum packaging preserved viability more than nitrogen packaging of samples. He also noticed *Streptococcus lactis* had less loss of activity in storage at 0° C. than at 30° to 37° C.

The purpose of this investigation was to study some of the common factors which may affect the growth rate of lactic cultures dehydrated with spray process milk drying equipment.

GENERAL EXPERIMENTAL PROCEDURE

A laboratory-size spray drier was used for the trials. The stainless steel cone-shaped drying chamber was 60 inches high; the top diameter was 37 inches and the bottom diameter was 4 inches. The outlet duct for the product was connected to a small cyclone collector. Capacity was approximately 30 pounds of water removal per hour. The air was heated with a direct-flame gas heater capable of attaining a temperature of 600° F.

Starter in 10-gallon amounts was prepared from active cottage cheese cultures according to the principles of good practice. The acidity usually was 0.80 to 0.85 percent after 16 hours of incubation. The starter was then cooled with flowing water. Shortly before dehydration, the starter was homogenized at 1500 p.s.i. to assure a smooth body and freedom from clogging of the nozzle.

Preliminary trials indicated that the standard plate counts did not measure the growth rate of the lactic organisms accurately. The growth rate (activity value) was measured by testing for the acid development in skimmilk. The procedure consisted of inoculating 1 gram of dry culture into 99 ml. of high heat pasteurized (190° F. for 30 minutes) skimmilk at 72° F. and incubating 16 hours. The percent acidity was ascertained by titrating a 9-gram sample with 5 drops of phenolpthalein indicator and 0.1 N. sodium hydroxide. The percent acidity multiplied by 100 was designated as "activity value." Inoculated samples before incubation usually had an activity of 15.

PROCEDURE DETAILS AND RESULTS

Air Drying Temperature

The inlet air temperature was controlled to within a narrow range of the desired setting for the trial. The activity value of the first 60 samples indicated there was no direct correlation between inlet air temperature and initial activity value of the lactic organisms.

The outlet air temperature was more difficult to maintain within a narrow range during the trial (approximately ¾ hour). Generally, this range was 5° or 6° F. although it varied as much as 10° F. during some trials. Figure 1 shows the initial activity plotted against the average range of the outlet air drying temperature. The temperatures recorded during the investigation of other factors further confirm the trend that is shown in Fig. 1.

Outlet temperatures of 195° F. or above drastically inhibited the activity of the lactic organisms. Often little growth occurred as measured by the activity test. Between outlet air temperatures of 170° and 190° F., activity values were 45 to 70. Outlet air temperatures of 165° down to 135° F. yielded dry cultures with high activity values. These usually were above 70. Some were as high as 86.

Reduction of Acidity

Just before dehydration, the culture acidity was reduced by the slow addition of a diluted solution of neutralizing agent (sodium hydroxide or calcium hydroxide) with vigorous agitation.

Figure 2 shows the average activity value of dehydrated lactic samples plotted against culture acidities of 0.80, 0.60, 0.40, 0.20 and 0.00 percent before drying. The average initial acidity was 0.80 percent and the activity value was 72.

As the acidity decreased by the addition of sodium hydroxide from 0.60 to 0.00 percent, the average activity values declined from 67 to 24. Results of acidity reduction with calcium hydroxide were more erratic and, in general, indicated a more detrimental influence on the activity values. Four samples with acidity reduced to 0.60 percent had an average activity value of 30. Reduction to 0.40 percent lowered the activity value to 24.

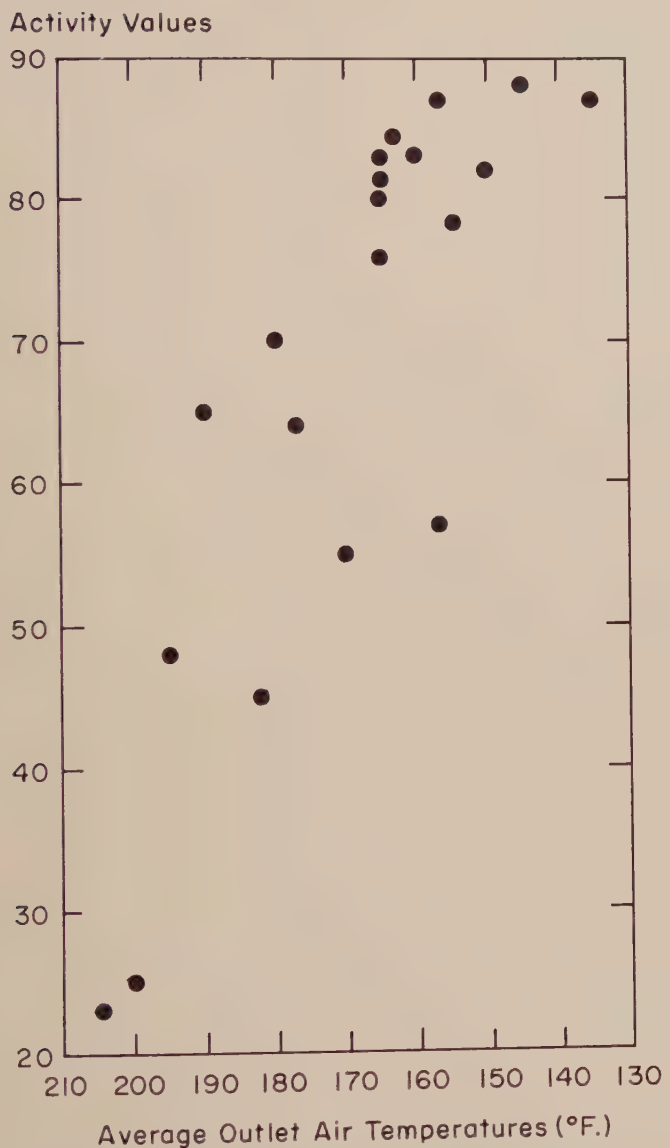

Fig. 1. The effect of outlet air drying temperatures on the initial activity of dehydrated lactic cultures.

Incubation Time

The average initial activity values of four series of dry lactic cultures from liquid cultures that were incubated 8, 12, 16 and 24 hours were 56, 61, 62 and 61, respectively. These results indicated

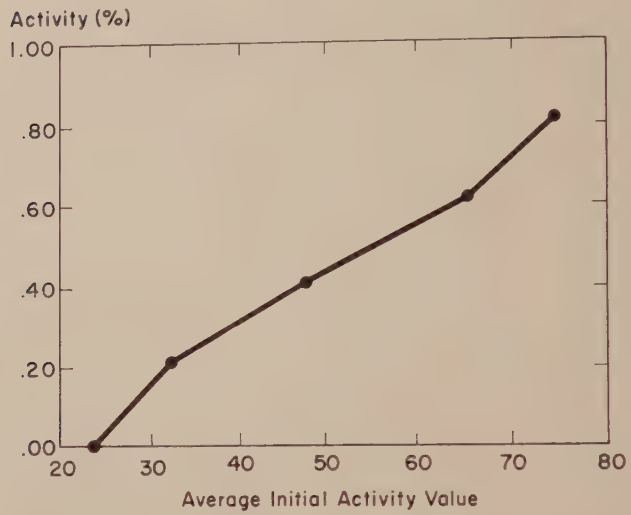

Fig. 2. The effect of culture acidity reduction with sodium hydroxide on the intial activity of the dehydrated lactic culture.

that 8 hours were not sufficient for the preservation of maximum cellular activity in the dry culture. There was little difference among 12-, 16- and 24-hour cultures. Higher air drying temperatures in half of the samples explain the low average initial activity values.

Addition of Gelatin

Gelatin was added to skimmilk on the basis of total solids before pasteurization, inoculation, incubation and dehydration. Initial activities of the samples with 0.05, 0.10, 0.50 and 1.00 percent gelatin were approximately the same as the control (70 to 86). Consequently any effect of the gelatin would have to become noticeable during storage.

Storage Period and Temperature

Nine samples of dry lactic cultures were held one year at —15° F. The initial activity values ranged from 70 to 86 and averaged 81. At the completion of the holding period, the activity range was 52 to 70. The average was 67. Three were below the satisfactory minimum limit of 70. Of these three, two were from samples with initial activity values just within the satisfactory limit.

Samples were held at 40°, 72° and 90° F. and were tested for

activity each week until the values were low. Tables 1 and 2 demonstrate the influence of holding temperature of the dry culture on the growth rate of the lactic organisms.

TABLE 1—The influence of storage on the activity of dehydrated lactic cultures with initial activities of 75 or above

Sample	Initial activity	40° F.				72° F.	90° F.
		Activity of samples after storage (days)					
		7	14	21	28	7	7
9	83	82	75	58	36	46	21
10	80	79	49	29	..	24	19
11	81	76	55	33	..	20	20
12	76	74	73	59	41	48	24
13	84	83	75	54	32	25	19
14	83	82	76	49	29	25	20
16	85	84	81	63	43	20	20
17	82	79	77	45	33	32	19
18	78	71	32	..	..	19	20
19	87	83	81	52	38	20	19
20	86	82	75	41	28	20	19
21	75	78	(Sample accident)		..	19	17
23	82	43	18	..	..	20	19
29	80	71	64	50	19	25	20
31	78	79	67	34	20	30	24
33	83	80	73	38	21	32	25

Samples with initial activity values of 75 to 86 usually decreased in activity only moderately during the first seven days of storage at 40° F. The average decline of these 16 samples was 5.7. Under the same conditions, 15 other samples with initial activity values of 40 to 65 dropped an average of 13.6 or more than twice as much as samples with higher initial activities.

Nine of the 16 samples with high initial activities were above 70 in activity value after 14 days at 40° F. The decrease averaged 17.0. By the end of 21 days, the decrease was pronounced which suggested a very retarded growth rate of the organisms. After 28 days at 40° F., the activity values of all but two samples were 38 or less (Table 1). Samples with initial activities of 40 to 65 were all below 38 after 14 days at 40° F.

The growth rates of lactic organisms in dry cultures seemed to decrease rapidly when stored at 72° F. or 90° F. The average activity value of 16 samples held at 72° F. (initially 76 or above) was

TABLE 2—The influence of storage on the activity of dehydrated lactic cultures with initial activities of 40 to 65

Sample	Initial activity	40° F.			72° F.	90° F.
		Activity of samples after storage (days)				
		7	14	21	7	7
3	48	36	21	..	25	20
4	65	59	26	..	22	21
5	45	31	21	..	22	..
7	64	49	28	..	21	22
8	55	38	29	..	22	..
15	57	46	34	..	21	..
22	56	46	21	..	16	21
24	40	22	20	17	20	18
25	51	49	24	..	21	18
26	54	50	36	24	20	19
36	45	31	23	19	15	15
37	43	28	24	19	15	16
38	55	21	18	..	15	15
42	40	28	25	20	16	16
43	41	25	23	19	16	15

26.7 and for those stored at 90° F., the average was 21.6. Results showed even less activity among the samples (Table 2) with lower initial activity during storage at 72° or 90° F.

Dry cultures containing gelatin did not have improved activity values in the storage tests. Apparently, the gelatin did not provide protection from the loss of activity during these holding conditions.

DISCUSSION

The importance of outlet air drying temperature in the preservation of active organisms during spray drying is not surprising. The evaporation of moisture takes place at the wet bulb temperature. The temperature of culture particles is low during the moisture evaporation, despite a high inlet air temperature. But, as the rate of evaporation of moisture begins to decrease, the temperature of the culture particles begins to increase to that of the outlet air. Consequently, a high outlet air temperature causes excessive heating of the organisms and loss of viability.

The cause of the detrimental effect of acid reduction of cultures before dehydration on the initial activity of the lactic organisms is not associated with a protective effect of the lactic acid. A limited

number of supplemental trials were made whereby cultures with acidities of 0.50 to 0.52 percent, due to a short incubation, were acidified to 0.83 percent. The results confirmed the lack of a protective effect from the acid.

Probably the salt (produced by the reaction between the base and the acid) or its ionization products exerted a depressing effect on the organisms. This influence did not appear to be lethal prior to drying because standard plate counts before and after acid reduction were practically the same. Very probably the heat during drying increased the influence of the neutralization products on the lactic organisms.

Cultures that were incubated 8 hours may have had lower initial activity values after drying because of the physiological age. The ability to survive the adverse effects of heat during drying may be improved by the age of the culture up to an optimum limit. Another factor may be that active survival is related to maximum counts in the liquid culture, other conditions being equal. However, variations in standard plate counts on dry cultures with comparable activity values tend to discredit this assumption.

The results of the storage tests; namely, diminishing activity with increasing temperatures and holding periods, are not unexpected. The same phenomenon occurs in nature. Vegetive cells perish with prolonged dry periods and rising temperatures. The exact processes that take place in the demise of the bacterial cell under these adverse conditions of time and temperature are not completely established. Presumably, the need for nourishment to maintain vital activities of cell life is a function of time and temperature. Undoubtedly, inherent characteristics of the species and individual cells within the species affect the rate of loss of vital activity and the recovery with improvement of conditions.

SUMMARY

The feasibility of dehydrating cheese cultures with conventional spray process equipment was studied by investigating several factors that are directly involved. The growth rate of organisms in dry cultures was measured by "activity value".

Results of the study show that, with favorable conditions, sufficient organism activity can be maintained during the production of dry

cultures to coagulate and produce normal acidities in high heat pasteurized skimmilk with 1.0 percent inoculation and incubation for 16 hours at 72° F.

As the outlet air temperature of a laboratory spray drier decreased from 200° to 170° F., the growth rate of the dry cultures improved. The most favorable outlet air temperature range was 135° to 165° F.

The reduction of acidity of cultures with sodium hydroxide or calcium hydroxide before dehydration progressively decreased the initial activity value.

A comparison of culture incubation times of 8, 12, 16 and 24 hours showed the least activity values from samples with the 8-hour incubation. Only minor activity differences occurred in the samples from the other three incubation times.

Addition of 0.05, 0.10, 0.50 and 1.00 percent gelatin prior to dehydration did not seem to affect the initial activity of the dry culture or the activity during storage.

Activity values of dry cultures that were held one year at -15° F. decreased moderately (from an average of 81 to an average of 67). Samples with high initial activity values (from an average of 75 to an average of 86) had a small average decrease at the end of one week at 40° F. The decrease was more pronounced thereafter and activity value was very low after 28 days. The decrease was more rapid in samples with the initial activities of 40 to 65. Dry cultures had little activity after storage of one week at either 72° or 90° F.

LITERATURE CITED

Downs, P. A. (1920). Bacterial flora of milk powder. Thesis, Cornell University, Ithaca, New York.

Higgenbottom, C. (1953). The effect of storage at different relative humidities on the survival of microorganisms in milk powder and in pure cultures dried in milk. Jour. Dairy Res. 20: 65-75.

Macy, H. (1928). Some observations on the bacterial content of dried milk. Jour. Dairy Sci. 11: 516-526.

Proom, H. and L. M. Hemmons (1949). The drying and preservation of bacterial cultures. Jour. Gen. Microbiol. 3: 7-18.

Rogers, L. A. (1914). The preparation of dried cultures. Jour. of Infectious Diseases. 14: 100-123.

Stark, C. N. and B. L. Herrington (1930). The drying of bacteria and the viability of dry bacterial cells. Paper presented at thirty-second annual meeting of the Society of American Bacteriologist, Boston, Mass.

THE EFFECT OF FEEDING CHLORTETRACYCLINE ON THE MILK PRODUCTION AND HEALTH OF MILKING COWS

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THE JUSTIFICATION OF FEEDING ANTIBIOTICS to ruminants has been in a state of confusion for several years. Early research work at a number of experiment stations including Iowa, Jacobson et al. (1952); Kansas, Bartley et al. (1953); Louisiana, Rusoff and Hag (1954), and Cornell, Loosli and Warner (1952) showed that cows fed the antibiotic Chlortetracycline did not produce any more milk than cows not fed the antibiotic. Boyd et al. (1960) recently reported similar results. All of this work was conducted in experiment station herds.

As yet no research has been reported where the antibiotic was fed under farm conditions. It is quite possible that the disease level in experiment station herds and commercial dairy herds are not the same. Thus, it seemed appropriate to study the value of antibiotics in the milking cow's ration under farm conditions.

The Food and Drug Administration in November of 1957 approved the feeding of Aureomycin (chlortetracycline) to milking cows. The approval was based on (1) that Aureomycin would not appear in the milk when a level of 0.1 mg. per pound of body weight daily was fed, and (2) this level of feeding would help prevent such diseases as foot rot, pneumonia and shipping fever. No claim in respect to milk production could be made, but soon after its release reports were received from the field that Aureomycin-fed cows were producing more milk than cows not fed the antibiotic.

In line with this interest among dairymen, a large scale field study was established to evaluate the feeding of this antibiotic under field conditions. All the previous data had been collected in university herds. The field study was started in April of 1958 and was completed in April of 1959. Cows were on test a total of 51 weeks

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during this time. The study was divided into two trials, one running from April until September and the second from October until the latter part of the following April. The first trial was 22 weeks long and the second 29 weeks.

The general plan was to select cooperator farm herds in a five county area in Southern Michigan. The only requirements placed on the cooperating herds was that they were (1) conveniently located, (2) presently using some type of production testing program, and (3) that they were willing to cooperate. In the first trial, there were 20 herds involving over 1,000 cows. In the second trial, were 14 herds involving sightly fewer cows.

A general description of the various herds is shown in Table 1. It can be noted that all breeds were involved except Ayrshire; herd size varied from 25 to 225 cows, production levels varied from 250 to 600 pounds of butterfat and both pen and stanchion type housing

TABLE 1—General description of cooperator herds

Herd No.	Trial(*a*)	Herd size	Breed	Type of housing	Approximate production level(*b*)
1.....	1 & 2	80	Guernsey.....	Conventional....	250
2.....	1 & 2	44	Holstein.....	Loose housing ...	450
3.....	1	36	Holstein.....	Conventional....	450
4.....	1 & 2	38	Holstein.....	Conventional....	450
5.....	1	50	Holstein.....	Switch.....	450
6.....	1 & 2	25	Jersey.....	Conventional....	375
7.....	1	55	Holstein.....	Conventional....	450
8.....	1 & 2	136	Brown Swiss. .	Conventional....	350
9.....	1 & 2	95	Guernsey.....	Conventional....	425
10.....	1	40	Holstein.....	Conventional....	600
11.....	1	80	Jersey.....	Conventional....	450
12.....	1	36	Holstein.....	Conventional....	450
13.....	1 & 2	45	Holstein.....	Conventional....	425
14.....	1 & 2	44	Jersey.....	Conventional....	325
15.....	1 & 2	43	Holstein.....	Conventional....	400
16-a.....	1 & 2	50	Holstein.....	Conventional....	450
16-b.....	1 & 2	95	Holstein.....	Conventional....	450
16-c.....	1 & 2	80	Holstein.....	Loose housing...	450
17.....	1	35	Jersey.....	Conventional....	425
18.....	1	60	Holstein.....	Loose housing...	350
19-a.....	2	50	Guernsey.....	Conventional....	325
19-b.....	2	25	Holstein.....	Conventional....	325

(*a*) Trial 1—April 9, 1958 to September 9, 1958.
Trial 2—October 8, 1958 to April 28, 1959.
(*b*) Herd average—Pounds of butterfat per cow yearly.

was involved. Holstein cattle did predominate due to the general cattle population in this section of the state.

Herds 16-a, b and c as well as herds 19-a and b were actually located on the same farm, but were handled as separate herds since they were located in separate barns. The herd size shown in Table 1 is the entire size of the milking herd and represents the total number of cows involved in the study, although the total numbers were not on trial at any one time.

Some explanation should be given as to why all herds did not participate in both trials. Herds 3, 7, and 17 were in the process of relocating and rebuilding, thus it was not convenient to cooperate. The operator of herd 10 installed a pipeline milker about six weeks after the beginning of Trial 2, thus it was not convenient to weigh the milk. Herd 18 was dropped due to poor cooperation and herds 5 and 11 started the second trial but dropped out about three weeks after starting due to a health problem which will be described later. Herd 12 did not wish to participate for personal reasons.

At the beginning of each trial, the milking cows within each herd were divided into two groups after considering milk production level and stage of lactation. One group of cows was fed Aureomycin at the rate of 0.1 mg. per pound of body weight daily and the other group of cows served as the controls. In all other respects, the feeding and management was the same for the two groups of cows. The Aureomycin was fed twice daily on top of the grain mix and was supplied by a commercial product, "Aureomycin Crumbles."

The cows were regrouped at the beginning of the second trial and two herds were added. In the first trial, the cows were brought on a full feed of Aureomycin in three days, but three weeks time was taken in the second trial. The milk from each cow was weighed one day each week. Some health records were kept, but these were not very complete.

Data collected under field conditions are subject to error due to the lack of control and supervision. Special attention was given to this problem when the study was established. Extra care was given to the selection of cooperators, design of the experiment, and the amount of research supervision.

In regard to the research supervision, a representative from the university visited each cooperator at least once every two or three weeks throughout the study. At this time, the progress of the experiment was reviewed with the cooperator and milk and health records

were checked for completeness. A close check was made of the quantity of Aureomycin being used by each herd to make sure the correct amount of the antibiotic was being fed.

RESULTS AND DISCUSSION

Milk Production

For the purpose of this report, only milk production records on cows that completed the entire 22-week trial were used in the analysis of the data in the first trial. In the second trial data of cows on test, 75 percent of the 29 weeks were included. In the first trial, this involved 519 cows and 366 in the second trial. In both trials, sufficient cattle were involved for valid results.

An analysis of the milk production data collected in the first trial showed that the Aureomycin-fed cows produced slightly more milk than cows not fed the antibiotic, 0.21 pounds more milk per cow daily. (See Table 2) This slight increase in milk production was not significantly greater than the production of the control cows.

Further analysis of the data showed that Aureomycin-fed cows were significantly more persistent in milk flow than the control cows. (See Table 3) There was some evidence that this was not a short time effect because when the data were analyzed by 11-week periods, there was a greater response over the entire 22-week trial than the first 11-weeks, thus making a greater response during the last 11 weeks of the trial.

There was a favorable response to Aureomycin feeding in 12 out of the 18 herds. No relationship existed between the amount of response and such things as breed, level of milk production, or herd size.

Analysis of the milk production data from the second trial (Table 4) showed that Aureomycin-fed cows average milk production was 1.81 pounds more per day than the control cows. This difference in milk production was highly significant; however, there was no difference in the persistency of milk production (Table 5), as had existed in the first trial. A favorable response to the antibiotic occurred in in 11 out of the 14 herds.

The milk production data of the two trials are combined and shown in Table 6. These data show that cows fed the antibiotic averaged 0.82 pounds more milk per day than the control cows. The

TABLE 2—Average milk production by herds in trial 1 (lbs./cow daily)

Herd No.	Treatment	Average daily milk production			Difference in groups(*c*)
		Initial	22-week av.	Adjusted(*b*)	
1	Control (14)(*d*)....	30.31	26.45	34.18	+0.12
	Aureomycin (11)..	30.04	26.36	34.30	
2	Control (9).....	36.08	34.94	38.29	−1.51
	Aureomycin (10)..	35.86	33.27	36.78	
3	Control (3).....	40.37	36.30	36.38	−2.46
	Aureomycin (6)...	47.28	39.10	33.92	
4	Control (9).....	60.17	50.32	35.34	+0.07
	Aureomycin (12)..	54.52	46.10	35.41	
5	Control (6).....	46.02	36.43	32.21	+5.59
	Aureomycin (6)...	48.31	43.77	37.80	
6	Control (9).....	22.49	24.60	38.28	+0.77
	Aureomycin (6)...	22.20	25.15	39.05	
7	Control (6).....	49.77	45.43	38.36	+2.97
	Aureomycin (6)...	45.05	44.82	41.33	
8	Control (37).....	34.04	32.32	37.22	−1.41
	Aureomycin (25)..	32.88	30.04	35.81	
9	Control (13).....	40.46	33.83	33.84	+0.73
	Aureomycin (9)...	41.82	35.60	34.57	
10	Control (6).....	51.95	38.28	29.55	+0.20
	Aureomycin (7)...	51.33	38.01	29.75	
11	Control (16).....	38.23	29.88	31.58	+1.02
	Aureomycin (21)..	30.54	25.04	32.60	
12	Control (2).....	49.85	40.45	33.31	−3.14
	Aureomycin (6)...	51.63	36.67	28.17	
13	Control (9).....	51.66	43.33	34.82	+1.91
	Aureomycin (7)...	52.48	45.86	36.73	
14	Control (9).....	36.31	27.19	30.35	+4.94
	Aureomycin (9)...	35.11	31.21	35.29	
15	Control (9).....	38.83	35.61	36.86	+0.49
	Aureomycin (12)..	42.60	38.97	37.35	
16 (*a*)	Control (67).....	43.49	41.47	39.17	−0.25
	Aureomycin (72)..	43.90	41.53	38.92	
17	Control (5).....	34.74	29.74	34.10	−7.15
	Aureomycin (4)...	42.90	28.80	26.95	
18	Control (9).....	35.84	34.29	37.81	+3.14
	Aureomycin (9)...	38.16	39.41	41.17	
	Weighted average.	.....	.....	.....	1.81

(*a*) Data handled as one herd in Trial 1.
(*b*) Adjusted for average pretreatment weight of 40.47 lbs./day.
(*c*) Difference = Aureomycin cows—control cows.
(*d*) Number of cows per group.

milk production response in the two trials was weighted in this final average due to the difference in the number of cows involved in each trial.

The question might be raised as to why the difference in the degree of response to Aureomycin in the two trials. First of all, the

first trial was conducted during the summer months or pasture season, whereas the second trial was in progress during the winter or barn feeding season. These data may indicate that cows responded more to Aureomycin feeding during winter months than during the summer. This is a definite probability, but cannot be stated as a fact. It is true that dairymen generally expect more disease problems during the barn feeding season.

Another contributing factor to the greater response to Aureomycin feeding during the winter trial involves some trouble encountered with an off-feed and bloat problem which will be discussed later. In the first trial, the data from cows that were troubled with this problem were included in the analysis, whereas data from such cows were not included in the analysis of the second trial, due to the fact that most of the herds having difficulty did not continue to cooperate. Undoubtedly, if the data of cows affected with the bloat in the first trial had not been included in the analysis, the response to Aureomycin

TABLE 3—Rate of decrease of milk flow (lbs./week) in trial 1

Herd No.	Group		Difference(*a*)
	Control	Aureomycin	Aureomycin minus control
1	0.540	0.635	−.095
2	0.608	0.532	−.076
3	0.747	1.200	.453
4	0.834	0.748	−.086
5	0.995	0.909	−.086
6	0.323	0.227	−.096
6	0.656	0.624	−.032
8	0.474	0.346	−.128
9	0.588	0.615	.027
10	0.786	0.379	−.407
11	0.654	0.464	−.190
12	0.490	1.327	.837
13	1.025	0.895	−.130
14	0.476	0.369	−.107
15	0.743	0.636	−.107
16(*b*)	0.338	0.289	−.049
17	0.716	0.500	−.216
18	0.865	0.709	−.156
Weighted average.....			−.078

(*a*) A negative is associated with greater persistency.
(*b*) Considered as a single herd in Trial 1.

TABLE 4—Average milk production by herds in trial 2 (lbs./cow daily

Herd No.	Average milk production(*a*)			Difference(*a*)
	Pretreatment	Control	Aureomycin	Aureomycin minus control
1.....	29.61	17.40 (7)(*c*)	19.22 (*c*)	1.84
2.....	48.19	31.76 (5)	28.28 (4)	−3.48
4.....	57.54	46.40 (3)	42.04 (6)	−4.36
6.....	23.38	22.34 (4)	24.03 (4)	1.69
8-a(*b*)....	41.33	28.51 (16)	35.71 (24)	7.20
8-b(*b*)....	39.61	32.95 (11)	31.09 (13)	−1.86
9.....	38.48	28.15 (12)	27.78 (7)	−0.37
13.....	55.00	35.63 (3)	48.08 (5)	12.45
14.....	19.96	24.99 (7)	28.97 (3)	3.98
15.....	45.72	35.21 (6)	43.75 (5)	8.54
16-a.....	51.62	37.81 (9)	39.58 (16)	1.77
16-b.....	50.08	41.23 (20)	41.38 (24)	0.15
16-c.....	53.24	39.48 (20)	39.54 (18)	0.06
19-a.....	27.99	21.76 (9)	22.78 (10)	1.02
19-b.....	32.22	21.61 (1)	25.11 (3)	3.50
Weighted average.....				1.81

(*a*) Adjusted milk production for difference in initial milk production.
(*b*) This herd analyzed as two herds due to management practices in second trial.
(*c*) Number of cows per group.

would have been greater. However, there is very little possibility that very much of the added response during the winter feeding trial could be explained in this manner.

The increased milk production of cows fed Aureomycin observed in this study is not in agreement with the results of other research work referred to earlier. Two explanations are offered for this difference. First, the level of response to such a product is extremely hard to detect in most experiments conducted under experiment station conditions. This is due to the small number of cattle usually available and the variable response quite often observed with cattle.

Probably a more significant reason is the comparative disease level of research and commercial dairy herds. It is believed that the disease level of commercial dairies is usually higher than the disease level of research herds. Thus, a greater response to antibiotic feeding might be expected under field conditions. Products such as antibiotics probably can best be evaluated under field conditions, even though the deficiencies of such research work are well recognized.

Magruder (1960) recently reported the results of a field trial

TABLE 5—Rate of decrease of milk flow (lbs./week) in trial 2

Herd No.	Group		Difference
	Control	Aureomycin	Aureomycin minus control(*a*)
1	0.329 (12)(*c*)	0.358 (5)(*c*)	−0.029
2	0.475 (6)	0.730 (5)	−0.255
4	0.792 (4)	0.779 (8)	0.013
6	0.524 (4)	0.651 (5)	−0.127
8-a(*b*)	0.618 (19)	0.416 (32)	0.202
8-b(*b*)	0.557 (15)	0.395 (19)	0.162
9	0.419 (18)	0.462 (10)	−0.043
13	0.596 (5)	0.651 (7)	−0.055
14	0.393 (15)	0.475 (13)	−0.082
15	0.612 (13)	0.725 (11)	−0.113
16-a	0.819 (9)	0.708 (16)	0.111
16-b	0.734 (20)	0.796 (24)	−0.062
16-c	0.823 (20)	0.822 (18)	0.001
19-a	0.524 (17)	0.375 (10)	0.149
19-b	0.521 (2)	0.688 (4)	−0.167
Weighted average			0.000

(*a*) A negative value is associated with greater persistency.
(*b*) This herd analyzed as two herds due to management practices in second trial.
(*c*) Number of cows per group.

involving about 3,000 cows. The results of this work confirm the results of this trial. Cows fed a low level of Terramycin produced 0.87 pounds more milk daily than cows not fed the antibiotic.

Other Observations

As previously stated, an attempt was made to obtain accurate health records, but the records obtained were not very adequate except in a few herds. Thus, any observations about the effect of

TABLE 6—Summary of milk production data for both trials

	Control	Aureomycin
Number of cows	437	448
Average daily milk production	33.34	34.38
Average difference in daily milk production	.....	1.04
Average difference in daily milk weighted for difference in herd size	.....	0.82

TABLE 7—Data relative to the occurrence of bloat in cows fed Aureomycin

Herd No.	Herd size	Cases of bloat		Number of cows involved	
		Trial No.		Trial No.	
		1	2	1	2
1	80	0	0	0	0
2	44	0	0	0	0
3	36	0	..(d)	0	..
4	38	1	0	1	0
5(a)	50	10	..	8	..
6	25	0	..	0	..
7	55	3	..	3	..
8	136	0	0	0	0
9	95	18	6	8	6
10(b)	40	1	5	1	3
11(c)	80	0	7	0	3
12	36	2	..	2	..
13	45	3	0	3	0
14	44	3	0	3	0
15	43	2	2	2	2
16-a	50	0	0	0	0
16-b	95	0	0	0	0
16-c	80	0	0	0	0
17	35	0	..	0	..
18	60	0	..	0	..
19-a	50	..	0	..	0
19-b	25	..	0	..	0
	Total	43	20	31	14

(a), (b), (c) Only participated in second trail for about 3 weeks.
(d) (..) Indicates herds that did not participate in second trial.

Aureomycin on herd health are based more on personal observation than fact. Dairymen varied greatly in their opinion about the effects of the antibiotic on herd health.

In one herd, evidence was obtained which would support the fact that low level Aureomycin feeding does help to prevent the disease "pink eye." This herd was located in an area where "pink eye" was prevalent and this herd was affected by the disease. In this herd of about 50 cows, all in the control group contracted the disease and some animals had rather severe cases. Only one cow in the Aureomycin-fed group contracted a slight case of pink eye and she had only been on Aureomycin feeding for about three weeks. This is not conclusive proof that Aureomycin feeding prevents pink eye under all conditions, but this observation is interesting.

An attempt was made in the second trial to get some indication as to whether Aureomycin feeding does have a beneficial effect on mastitis. The three herds at the Southern Michigan Prison, 16-a, 16-b and 16-c, were involved in this study and very complete herd health records were available. Unfortunately, the incidence of mastitis was extremely low in the entire herd, thus any observation in this regard would not be significant.

The response to Aureomycin feeding in these three herds was variable and the averages showed little difference, probably due to the high degree of sanitation practiced and the low level of infection. This observation gives strength to the fact that low level antibiotic feeding reduces the level of subclinical infections; some herds probably would not respond to the antibiotic. This may be the reason some herds in this study did not show increased production due to Aureomycin feeding.

The only other significant observation in respect to herd health was the off-feed bloat condition mentioned earlier. To the knowledge of the authors, such a condition has never been associated with the feeding of low levels of antibiotics to dairy cows or other ruminants. This problem was first encountered about 3 to 4 days after bgeinning the first trial—actually before the cows changed from a winter to summer feeding regime. Most of the bloat occurred within the first 3 to 4 weeks of the trial, but two herds experienced their first bloat 10 to 12 weeks after feeding of Aureomycin started.

The same observation was repeated when the second trial started. One herd had no bloat in the first trial, but encountered bloat when the second trial started. Some of the herds that encountered bloat at the beginning of the second trial did not choose to participate further in the study. Thus they were removed from the experiment at this time. This eliminated the possibility of knowing whether these herds would have had bloat later in the trial.

A summary of these bloat observations is shown in Table 7. Ten out of the 22 herds involved in both studies experienced some trouble with bloat. This does not mean that every cow in these herds which was receiving Aureomycin had trouble with bloat, but that at least one case occurred within the herd. A total of 45 cows of the 1,000 fed Aureomycin experienced at least one case of bloat. Only one case of bloat appeared in the control cows, which is certainly below normal.

A case of bloat would develop with a cow being slightly off-feed for 12 to 24 hours and then bloating before going back on feed. The bloat appeared to be of the gas type and was readily cured by treating with oil or some other similar material. Only one death resulted from the bloat and this occurred the first day the herd was fed green chop. Usually, a particular cow would bloat once but some cows bloated more than once.

The most successful cure of the bloat problem was to cut the feeding of Aureomycin in half for one week and then bring the cow back on full feed. In almost all cases when this procedure was followed, bloat would not recur. The only relationship found with the incidence of the bloat was the production level of the herd. In no case did bloat occur in one of the lower producing herds. This might indicate that the occurrence of the bloat may be related to such factors as total feed intake and over-all stress, since both would probably tend to increase as production level increased.

In most cases, the problem of bloat does not seem to be a limiting factor in feeding Aureomycin to milking cows, but the possibility of occurrence must be recognized.

SUMMARY

A 51-week feeding trial was conducted with 22 cooperating dairy herds to study the effect of feeding Aureomycin on the milk production and general health of dairy cows. One-half of the cows within each herd was fed Aureomycin and the other half was not fed the antibiotic and served as the controls.

Milk production data collected during the 22-week summer trial showed that average production of Aureomycin-fed cows was 0.21 pounds more milk per day than cows not fed Aureomycin. In a 29-week winter trial, the Aureomycin-fed cows averaged 1.81 pounds more milk per day than the control cows. Combining the milk production data of the two trials, it was found that the cows fed Aureomycin produced 0.82 pounds of milk more per day than the cows not fed the antibiotic.

Observations concerning herd health were limited and the resulting data are inconclusive. Some evidence was obtained that cows fed Aureomycin have more resistance to pink eye infection. Some bloat was encountered that was associated with the feeding of Aureomycin. The bloat usually occurred as part of an off-feeding condition and

most of the bloat appeared during the time the cows were going on Aureomycin feeding. In most cases, the bloat problem was cured by cutting the level of Aureomycin by one-half for one week and then bringing the cows back on full feed of the antibiotic slowly.

REFERENCES

Bartley, F. E., F. C. Fountain and F. W. Atkeson (1953). Antibiotics in dairy cattle nutrition. II. Effect of feeding an Aureomycin product (Aurofac 2A) to lactating dairy cows. Jour. Dairy Sci., 36: 402.

Boyd, L. S., H. D. Baxter, J. B. McLaren and J. A. Nichols (1960). Effects of feeding Aureomycin to lactating dairy cows. Jour. Dairy Sci., 43: 661.

Jacobson, N. L., J. G. Kaffetzakis and P. G. Homeyer (1952). Effects of Aureomycin supplements on changes in weight and body measurements of dairy calves. Jour. Dairy Sci., 35: 493.

Loosli, J. K. and R. C. Warner (1952). Antibiotics for dairy animals. *Farm Research* 18: 3.

Magruder, W. D. (1960). Antibiotics in milk production. Proc. 8th Chas. Pfizer Research Conf. p. 61.

Rusoff, L. S. and M. O. Hag (1954). Studies on Aureomycin and vitamin B_{12} supplementation for dairy cows. II. Effect on production, composition and vitamin B_{12} content of the milk Jour. Dairy Sci., 37: 677.

A MECHANICAL RECORDING PRESSURE TESTER

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THE "PRESSURE TEST" is a common objective measure of attributes of fruits and vegetables. It is widely used for indicating changes in maturation and ripening of apples, peaches, and pears, and as an index of texture in pickles. It is used extensively in experimental work to follow changes in firmness. The USDA (Magness-Taylor) fruit pressure tester[2] as modified and presently manufactured[3] is the standard in the fruit and vegetable industry. Results of experiments carried on in this laboratory indicate that there may be significant differences in the results obtained by different operators using the hand powered Magness-Taylor pressure tester.

This is a report of the development of a mechanically operated recording pressure tester designed to eliminate part of the human element from pressure testing and, at the same time, provide a force-displacement diagram for a better understanding of the behavior of the product during testing.

Construction and Operation

Fig. 1 is a labeled photograph of the mechanical recording pressure tester; the pedestal, including rack and pinion, was formerly part of a spring tester.

The mechanical recording pressure tester operates in a manner similar to the Magness-Taylor pressure tester where a plunger of standard dimensions is forced into the fruit to a fixed distance and the resistance of the fruit to penetration is measured. In the Magness-Taylor pressure tester, the force for penetrating the fruit is supplied by the operator and measured by the displacement of a calibrated spring.

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[2]Magness, J. R. and G. F. Taylor (1925). An improved type of pressure tester for the determination of fruit maturity. USDA Circular No. 350.

[3]Ballauf Mfg. Co. Inc., Washington, D. C.; Model 30A.

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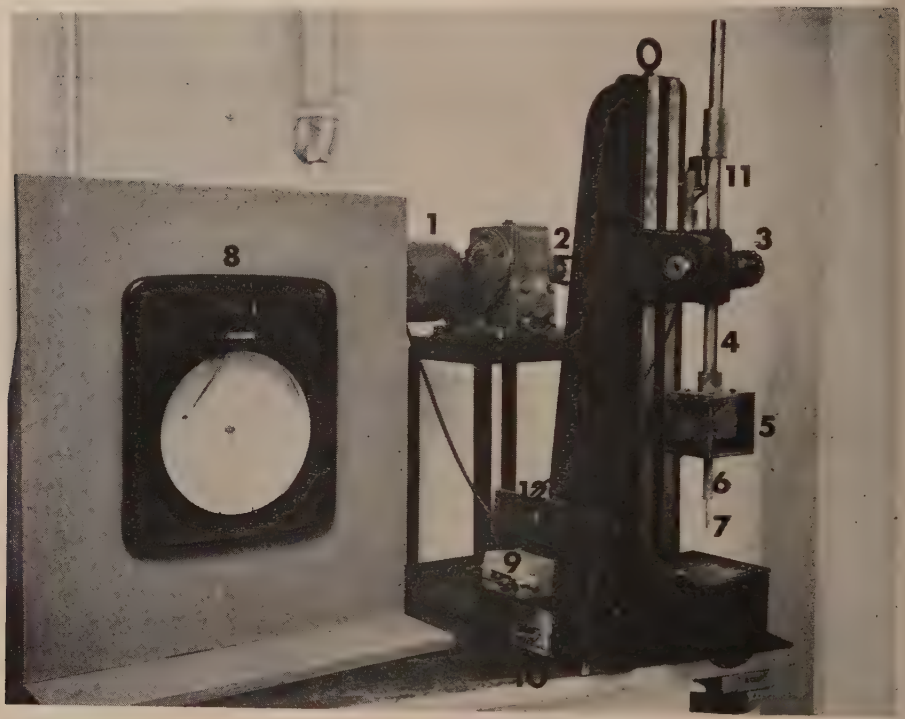

Fig. 1. Mechanical recording pressure tester. 1. Motor, 2. Drive sprocket, 3. Pinion sprocket, 4. Rack shaft, 5. Load cell, 6. Safety sleeve, 7. Plunger and tip, 8. Recorder, 9. Reversing switch, 10. Chart drive switch, 11. Microswitch and sleeve, and 12. Microswitch bypass.

The plunger of the mechanical recording pressure tester is powered by a 1/6-H.P. constant speed reversible electric motor acting through a mechanical power train. The resistance of the fruit to penetration is measured by a Baldwin SR-4 type load cell (50 lb. capacity)—Foxboro Dynalog resistance bridge system. The pressure in pounds is recorded directly on a circular chart that rotates at 1 rpm.

The operator of the mechanical recording pressure tester controls the direction of plunger movement with the electric motor reversing switch. The chart drive motor is powered from the "down" side of the reversing switch so that the chart moves only when the plunger is moving downward. A separate chart drive switch allows the chart drive motor to be disconnected even when the plunger is moving downward. This permits the necessary flexibility if only the maximum force is wanted rather than a force-displacement diagram.

The system is equipped with several safety devices designed to

limit the travel of the plunger and to protect the load cell. A microswitch in series with the plunger motor may be adjusted to stop the plunger at any desired point by adjusting the sleeve that actuates the microswitch. The total plunger travel is governed by the length of the microswitch sleeve. A microswitch bypass (which allows the operator to move the plunger when the microswitch is open) is located on the control panel just above the motor reversing switch. A spring safety sleeve is located between the load cell and the plunger; if the force on the plunger exceeds 30 lbs. the plunger will compress the spring and move against a stop rather than transfer the force to the load cell. The plunger drive motor electrical circuit passes through the control section of the Foxboro Dynalog instrument, which provides an additional safety feature to prevent overload of the load cell. The controller is adjusted so that the motor will be turned off when the test force exceeds 30 lbs.

Plunger speed may be varied by changing the drive-sprocket-pinion-sprocket tooth ratio. This operation requires only a few minutes. The speed is governed, in addition, by the drive motor output, 1.91 rpm, the number of teeth on the pinion, 13, and the number of teeth on the rack shaft, 46 teeth ft. The plunger speed, s, is calculated to be

$$s = \frac{\text{no. drive sprocket teeth}}{\text{no. pinion sprocket teeth}} \times \frac{1.91 \text{ rev.}}{\text{min.}} \times \frac{13 \text{ teeth}}{\text{rev.}} \times \frac{12 \text{ in.}}{46 \text{ teeth}}$$

$$s = \text{tooth ratio} \times 6.48 \text{ in./min.}$$

In the tests described herein, tooth ratios of 12:26, 12:12, and 26:12 were used; the corresponding speeds are, respectively, 3:00, 6.48, and 14.0 in./min.

The instrument was calibrated by placing known weights up to 20 lbs. on the plunger sleeve. The recorder response is linear over the range 0-20 lb. and the force may be estimated to the nearest 0.2 lb. The angular distance on the chart, which is a measure of plunger displacement, is different for each plunger speed; for example, 0.146 in./chart division at a plunger speed of 14.0 in./min.

The data may all be taken in chart divisions, manipulated, and converted to inches at the end or a template may be made for reading the displacements directly in inches. If displacement data are found to be particularly useful, it is recommended that a suitable juggling of chart and plunger speeds be made or that special charts be designed. A strip

chart recorder would facilitate the analysis of large amounts of force-displacement data.

The sleeve at the bottom of the Baldwin SR-4 load cell was designed for use with several types of plungers. The plungers are mounted in the lower end of the mounting sleeve and held in place with a set screw. In the original work using this instrument, several different head shapes were used; for comparative work with the Magness-Taylor fruit pressure tester, an adaptor is used so that the plunger tip of the Magness-Taylor fruit pressure tester can be attached to the mechanical pressure tester.

Application

Fig. 2 shows curves for two fruits tested with the recording pressure tester (5/16″ fruit pressure tester tip, plunger speed 6.48 in./min.). These curves have been redrawn from the circular charts for the read-

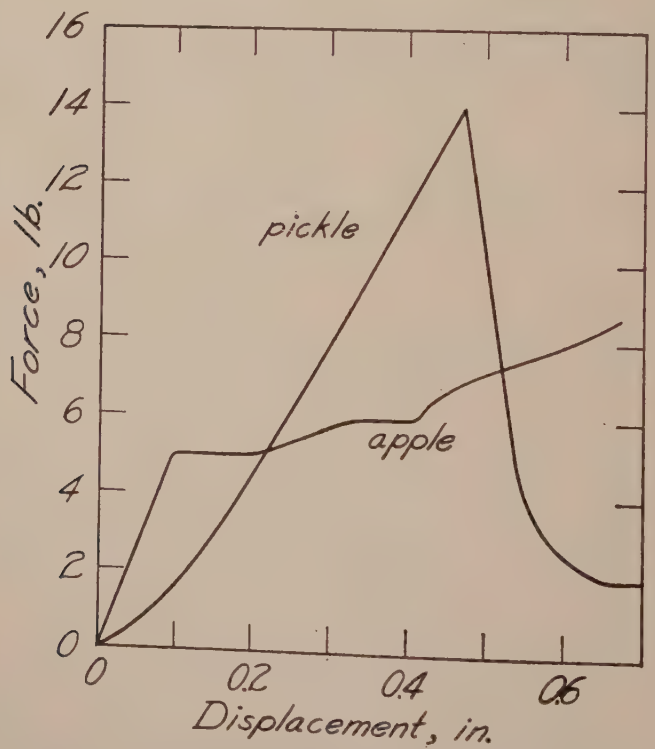

Fig. 2. Force-displacement curves obtained using the mechanical recording pressure tester (plunger speed 6.48 in./min., 5/16 in. tip).

er's convenience. According to recommended procedure,[4] the apple was punched after removing a section of skin; the salt-stock pickle was punched through the skin. The area under the curve is a measure of the energy expended in doing the work of puncturing the fruit.

Table I gives the results of punching salt-stock pickles at three plunger speeds. The variables measured were the force at which the fruit failed under load, the area under the curve (energy) up to the point of failure, and plunger displacement at the point of failure. Displacement is measured from the skin of the fruit toward its center. The standard deviations of the variables at each speed were tested by the F-test and were not significantly different. An analysis of variance of the data showed no significant difference in yield force means or energy means at the three speeds. The displacement means are significantly different among all three speeds. This difference is probably related to the relaxation time for the fruit.

TABLE 1—Characteristics of pickle force-displacement curves obtained with the mechanical recording pressure tester (5/16 in. tip)

Variable	No.	Plunger speed, in./min.			Standard deviation
		3.00	6.48	14.0	
Force, lb.	30	14.8	15.6	15.8	1.9
Energy, in.-lb.	15	3.71	3.33	3.13	0.75
Displacement, in.	15	0.547	0.491	0.443	0.058

The mechanical recording pressure tester was designed as a research tool. Some of its advantages are permanent record of force vs. displacement, and elimination of personal idiosyncrasies. Some of its disadvantages, vis-à-vis, hand pressure testers are higher initial cost, fewer tests per hour (about 100) and it is not portable.

SUMMARY

The construction and operation of a fruit and vegetable pressure tester having a mechanically driven plunger and force vs. displacement recording system is described. Examples of the application of this apparatus are presented.

[4]Haller, M. H. (1941). Fruit pressure testers and their practical application. USDA Circular No. 627.

THE RELATIVE CLEANABILITY OF DAIRY PROCESSING EQUIPMENT HAVING VARIOUS FINISHES[1]

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INTRODUCTION

THE RELATIVE CLEANABILITY of various finishes of stainless steel in dairy processing equipment under actual plant conditions has not been resolved. The finish has a significant effect on the intial cost of processing equipment, and until recently the effect of the finish on cleanability has not been evaluated. The relative cleanability of stainless steel with various finishes has been studied under laboratory conditions by Kaufmann[2] and Masurovsky,[3] and the cleanability of a farm bulk tank with various finishes has been studied by Kaufmann.[4]

Kaufmann[2, 4] found no significant difference in the relative cleanability of Type 302 stainless steel with 2B, 3, 4, and 7 finishes. Masurovsky[3] found no significant difference between finishes 4 and 7. In all three of these studies, soiling was done at low temperatures which may give results different from those obtained using high temperatures for soil deposition.

Two pieces of dairy processing equipment, a plate heat exchanger (HTST unit) and a pasteurizing vat with various finishes, were studied under commercial conditions as part of a study designed to answer the question of the relative cleanability of stainless steel finishes under processing conditions.

[1]This project was supported in part by the American Iron and Steel Institute and the National Association of Dairy Equipment Manufacturers.

[2]Kaufmann, O. W., T. I. Hedrick, I. J. Pflug, C. G. Pheil, and R. A. Keppeler (1960). Relative cleanability of various stainless steel finishes after soiling with inoculated milk solids. Jour. Dairy Sci. 43: 28.

[3]Masurovsky, E. G., and W. K. Jordan (1958). Studies on the relative cleanability of milk contact surfaces. Jour. Dairy Sci., 41: 1342.

[4]Kaufmann, O. W., T. I. Hedrick, I. J. Pflug, C. G. Pheil, and R. A. Keppeler (1960). Relative cleanability of various finishes of stainless steel in a farm bulk tank. In press.

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EXPERIMENTAL

Description of Equipment

The heating section and the cooling section of the HTST unit each contained 13 plates (6 sets plus 1); the regenerative section contained 29 plates. Three plates of each finish, 2B, 3, 4 and 7, were placed in the heating section in a randomizd manner to study the effect of location on cleanability since soil deposition in a HTST unit is not uniform.

A 150-gallon rectangular, spray-type pasteurizing vat with the lining specially fabricated from Type 302 stainless steel with Nos. 2B, 3, 4, and 7 finishes was used in these studies. The panels with the Nos. 2B and 4 finishes were 37 × 22.5 inches; the 3 and 7 were 42 × 22.5 inches. The bottom was made from stainless steel with No. 4 finish. All welds were polished equivalent to that of a No. 4 finish. The water and steam valves for heating or cooling were manually operated. The heating medium (a hot water spray) was circulated by a centrifugal pump at approximately 10 gallons per minute.

Soiling Procedures

The HTST plates were soiled in the normal heating of whole milk containing 3.5 per cent milk fat to a temperature of 165° F. The flow rate through the unit was approximately 7000 pounds per hour; operating time of the HTST unit varied from 4 to 6 hours per day.

A typical operating cycle for pasteurizing 140 gallons of whole milk at 148° F. for 30 minutes was used to soil the pasteurizing vat. The heating system was adjusted so that the temperature of each heating surface of the vat was the same, since it was assumed that soil deposition on a heating surface would be related to the heat transfer rate. Following pasteurization, the milk was cooled to a temperature of 136-140° F. and then pumped from the vat. When the pasteurizing vat was empty, cold tap water was fed into the jacket to cool the unit.

Soil deposition on the sides of the vat was variable. It appeared that the rectangular shape of the vat and the location of the agitator were responsible for the uneven soil deposition. A dramatic demonstration of the variation in soiling and the location of the soil was obtained when chocolate milk was pasteurized in the vat instead of whole milk.

Cleaning Procedures

The HTST unit was cleaned using a CIP procedure. At the end of the pasteurization operation, the system was flushed with cold water until the water draining from the unit was clear. With the press open slightly, five pints of organic acid cleaner in 70 gallons of water were recirculated at 175° F. for 30 minutes. A slurry containing 5 pounds of an alkaline detergent was added directly to the acid solution and recirculation continued at 175° F. for another 30 minutes. The detergent solution was removed by rinsing the system with water at 162° F. for 15 minutes. To minimize air contamination, the system was drained at the lowest point. The plates were bacteriologically tested before the unit was sanitized with a chlorine solution.

The pasteurizing vat was cleaned using a modified CIP procedure. A special cleaning device was constructed consisting of four tubes arranged so that one tube was parallel to each side of the tank; the horizontal distance from a tube to the side of the tank was ½ inch. The tubes were 30½ inches long with 1/16-inch holes drilled 1/4-inch O. C. The rinse or washing solution was pumped into an inner tube with holes located 180° from the holes in the outer tube; this gave a uniform distribution along the whole length of the tube. The tubes were rotated so that the angle between the spray streams and the surface of the vat was 73°. The liquid flow rate was 20 gpm for 119 lineal inches of vat.

The pasteurizing vat was cleaned immediately after use. To clean the vat, the washing device was placed in position and 10 gallons of water at 125° F. were sprayed on the soiled walls. This rinse was followed by recirculating a cleaning solution at 165° F. containing a non-chlorinated non-foaming alkaline detergent (1 oz. per gal. of water) for 15 minutes. Ten gallons of water at 125° F. were used as a post-wash rinse. The surfaces were bacteriologically tested before sanitization.

The water used in the cleaning studies had a hardness of approximately 200 p.p.m.

Testing Procedures

The plates in the HTST unit were evaluated bacteriologically using a modifed standard Swab Test.[5] An area of 80 square inches was examined instead of the standard 40 square inches to obtain a more accurate sampling because of the low total bacterial count. A special

arge swab approximately 3/4-inch in diameter was used to swab the greater portion of the area between adjacent peaks on the corrugated plate; the actual area of each valley was approximately 5.75 square inches.

To randomize the test areas, five corrugations were selected near the top of the plate; four were taken from the middle section; and five were taken from the lower section of the plate. Each corrugation was tested by passing a moistened swab along the entire length of the valley three times while rotating the swab stick. After swabbing seven corrugations, the swab was whip-rinsed in 12 ml. of sterile phosphate buffer.

Immediately after testing, 4 ml. volumes of the swab solution were plated directly using plate-count agar. All plating was done in duplicate; the plates were counted after incubation for 48 hours at 95° F. The total number of bacteria removed from each plate was calculated, and the results of these tests are shown in Table 1.

The standard Swab Test,[5] utilizing a 40-square inch test surface, was used to determine the bacterial cleanability of the pasteurizing vat. Three different 40-square inch areas on each finish were tested. Duplicate 4-ml and 1-ml plates were poured; they were counted after 48 hours incubation at 95° F.

RESULTS AND DISCUSSION

The bacteriological results on the HTST unit obtained with the swab test are given in Table 1. These values represent the actual counts obtained from an 80-square inch area on each of three different plates having the same finish. An analysis of variance indicates no significant difference at the 5 per cent level in the bacteriological cleanability of the Nos. 2B, 3, 4, and 7 finishes.

Preliminary evidence indicated that soil build-up on the heater section increases from the milk inlet to the outlet port. However, an analysis of variance indicated no significant difference in bacterial counts among the various finishes regardless of location.

Compliance with the maximum recommended standard[5] of 12.5 organisms per square inch was observed 100 percent of the time, notwithstanding the fact that sanitization was omitted. Lower levels of bacterial contamination undoubtedly would have been observed if the HTST unit had been sanitized with chlorine prior to testing.

[5]American Public Health Association (1953). Standard Methods for Examination of Dairy Products. 10th ed.

TABLE 1—Bacteria counts on plates having No. 2B, 3, 4 and 7 finish in a HTST unit prior to sanitization

Trial No.	Number per 80 square inches(*a*)			
	No. 2B	No. 3	No. 4	No. 7
1	12	15	8	8
	24	14	12	14
	14	8	18	14
2	6	18	18	24
	33	6	27	3
	15	3	23	9
3	186	363	3	6
	14	90	3	2
	36	42	5	2
4	105	6	5	2
	6	8	12	8
	6	...	6	6
5	3	36	33	21
	20	6	5	23
	24	...	5	15
6	18	6	6	3
	9	2	9	2
	5	...	21	8
7	18	18	11	12
	18	8	12	14
	30	...	18	45
8	9	6	75	11
	3	9	9	9
	3	...	5	3
9	2	11	6	9
	9	3	6	6
	2	...	12	3
10	27	3	23	6
	6	8	32	50
	23	...	120	14
11	45	0	111	0
	3	2	69	5
	0	...	3	0
12	2	17	30	6
	15	6	5	8
	11	...	12	8

TABLE 1—Concluded

Trial No.	Number per 80 square inches(a)			
	No. 2B	No. 3	No. 4	No. 7
13	3	2	3	2
	0	270	3	3
	0	...	8	0
14	110	144	135	12
	0	0	3	3
	2	...	8	0
15	3	3	3	11
	2	5	5	3
	2	...	3	3
16	0	2	2	8
	3	3	15	2
	0	...	2	0

(a) Average of duplicate plates (Suggested maximum standard is 1000/80 square inches).

The average bacteriological results obtained on the vat using the Swab Test are given in Table 2. Visual inspection of the soil on the vat immediately after emptying indicated an uneven deposition of soil on the walls of the vat which, in turn, makes comparison of cleanability difficult. Since the cleaning procedure employed was sufficient to

TABLE 2—Bacteria counts on a pasteurizing vat after detergent washing

Trial No.	Number per 40 square inches(a)			
	No. 2B	No. 3	No. 4	No. 7
1	30	63	27	52
2	25	31	20	45
3	22	27	39	19
4	15	10	5	8
5	10	8	5	16
6	10	4	10	10
7	5	19	8	4
8	5	5	4	28
9	24	7	3	3
10	28	53	12	15
Gr. av....	17	24	13	20

(a) These values represent the average of three replications.

remove the soil on the surface having the greatest accumulation, it was possible to compare the surfaces notwithstanding this variation. An analysis of variance indicates no significant difference at the 5 per cent level in bacteriological cleanability between the 2B, 3, 4, and 7 finishes using the cleaning procedure described.

It is interesting to note that 100 percent compliance with the recommended standard[5] was observed after rinsing and washing, regardless of finish; the uneven soil deposition apparently did not influence the final bacteriological results.

SUMMARY AND CONCLUSION

The bacteriological cleanability of Type 302 stainless steel with finishes No. 2B, 3, 4, and 7 was tested under commercial processing conditions in a HTST unit and in a pasteurizing vat; the HTST unit was cleaned using a CIP cleaning procedure; the pasteurizing vat was cleaned using a modified CIP procedure. The results showed no significant difference in the bacterial counts at the 5 percent level among the four finishes.

Since there was no significant difference in the bacterial counts of the four finishes, it must be concluded that there is no difference in the relative cleanability of these four finishes and that any of these finishes should be satisfactory for dairy processing equipment from a sanitation standpoint. Therefore, selection of a Type 302 stainless steel finish (2B, 3, 4, and 7) to be used under conditions comparable to those existing in these tests will have to be based on criteria other than bacteriological cleanability.

ACKNOWLEDGEMENTS

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PRELIMINARY STUDIES OF HYDRO-COOLING OF PICKLING CUCUMBERS

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HYDRO-COOLING, A RAPID METHOD for removal of field heat, was tested to determine whether it could be used on pickling cucumbers without impairing the quality of the fresh cucumber pickle product. In tests in this laboratory, it had been observed that holding pickling cucumbers in water for 24 hours caused undesirable changes in the color and flavor of the pickles.

Test I

Six bushels of graded pickling cucumbers of the SMR-12 variety were obtained from a local receiving station. They were divided into eight lots, four of which were immediately hydro-cooled in an ice-water bath for 20 to 25 minutes. Two of the hydro-cooled lots, along with two comparable non-cooled lots, were stored at each of two temperatures, 40 and 60° F., for two days. Three quarts of whole dill pickles were manufactured from each of the eight lots of cucumbers. The pickles were evaluated approximately six months after packing by the method described by Cook et al.[1] In this method the experimental jars of pickles are evaluated and numerically rated by comparing each jar with a set of standards subjectively judged excellent, good, fair, poor, and very poor and numerically rated 9, 7, 5, 3, and 1 respectively.

Test II

Six bushels of graded SR-6 variety pickling cucumbers were divided into six lots. Two lots of cucumbers were hydro-cooled for 15 minutes, two lots were hydro-cooled for an hour and two lots were air-cooled

[1]Cook, J. A., I. J. Pflug and S. K. Ries (1957). Effect of cucumber holding time and temperature on the quality of pasteurized fresh whole pickles. Food Tech. 11: 216-218.

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and held at 40° F.; after cooling all cucumbers were stored four days at 40° F. Three quarts of whole dill pickles were manufactured from each of the two replications of each treatment. The pickles were evaluated using the same procedure as in Test I.

RESULTS

The results of the first trial of hydro-cooling vs. air-cooling are presented in Table 1. No adverse effects of hydro-cooling were found; in fact, in three of the four comparisons the pickles made from hydro-cooled cucumbers were of higher quality than the pickles made from air-cooled cucumbers. The mean values for treatments indicate that hydro-cooling was better than air-cooling at both temperatures, and that hydro-cooled cucumbers stored at 60° F., were of equal quality to air-cooled cucumbers stored at 40° F.

TABLE 1—Quality ratings of pickles made from hydro-cooled and air-cooled cucumbers stored two days. (1 equals good, 7 equals poor)

Cooling method	Storage temperature	Quality rating		
		Replication		Mean
		1	2	
Air-cooled	40°F	6.0	5.7	5.8
Hydro-cooled	40°F	5.3	5.0	5.2
Air-cooled	60°F	6.0	7.0	6.5
Hydro-cooled	60°F	6.0	5.7	5.8

The results obtained from cucumbers which were hydro-cooled for 15 minutes, hydro-cooled for 1 hour, and air-cooled are given in Table 2. The pickles from cucumbers hydro-cooled for 1 hour and from air-cooled cucumbers were judged to be better than the pickles from cucumbers hydro-cooled for 15 minutes.

Direct comparison of the results obtained in these two tests are not possible because different varieties and storage conditions were employed.

The absence of adverse effects in pickles made from cucumbers hydro-cooled for 1 hour warrants the conclusion that water temperature and duration of holding were probably responsible for the quality deterioration noted previously in pickles made from cucumbers that were held in water for an extended time before processing.

TABLE 2—Quality ratings of pickles made from cucumbers hydro-cooled for 1 hour, hydro-cooled for 15 minutes, and air-cooled. (1 equals good, 7 equals poor)

Cooling method	Quality rating		
	Replication		Mean
	1	2	
Hydro-cooled for one hour	3.0	3.7	3.4
Hydro-cooled for 15 minutes	4.0	4.7	4.4
Air-cooled	4.0	3.3	3.6

These results indicate that field studies should be carried out on hydro-cooling of pickling cucumbers to determine if this procedure is a commercially satisfactory method to improve the quality of pickles.

SUMMARY

Pickling cucumbers were precooled with air and water and stored two to four days at several temperatures prior to manufacture as fresh whole dill pickles. These preliminary trials showed that hydro-cooling for as long as one hour did not adversely affect pickle quality and indicated that hydro-cooling may be more effective than air-cooling for retarding deterioration.

UNLOADING SOFT-FLESHED FRUIT FROM BULK BOXES

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In many areas of the tree fruit industry, bulk boxes with 16 to 20 bushels capacity have replaced bushel containers. One major problem with bulk boxes has been the unloading of soft-fleshed fruits (firmness 10 lb. or less, as measured by the Magness-Taylor fruit pressure tester, 7/16 in. tip) destined for fresh market purposes and which are easily damaged by bruising and skin cuts or punctures.

McIntosh and Golden Delicious apples, removed from storage during the late winter and spring, suffer excessive mechanical damage when poured from bulk boxes by unloading devices[1, 2] that tilt and invert the container. Hand picking of the fruit from bulk boxes is impractical and offsets any savings in costs previously attained by bulk handling.

The design and operating characteristics of a more gentle unloading method, a water submergence bulk box unloading machine, is described below.

EXPERIMENTAL

Initial tests demonstrated that apples would readily separate from a container submerged in water, and that the containers in general use would quickly fill or empty when vertically submerged or raised out of a tank of water.

A study of the mechanism by which fruit and container separate in a floatation system led to the conclusion that vertical submergence of the bulk box of fruit would be one of the most satisfactory approaches. When the box of fruit is lowered into the water, the fruit in the box behaves as a unit, rather than as individual apples. The

[1]Pflug, I. J. (1955). Pallet box dumper. Mich. Agr. Expt. Sta. Quart. Bul. 38: 43-46.

[2]Levin, J. H. and H. P. Gaston (1957). A bulk box dumper for handling fruit. Mich. Agr. Expt. Sta. Quart. Bul. 39: 557-563.

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mass of fruit, buoyed upward with a force equal to the weight of water displaced, follows the box into the water until the buoyant force equals the weight of the mass of fruit.

At this point, approximately 80 percent of the volume of the total mass of fruit will be submerged and the box and fruit will start to separate (this is assuming a specific gravity of apples of 0.80 which was calculated on the basis of 25 percent air space in the fruit and 15 percent soluble solids, Smock and Neubert[3]).

In practice, the top apples in a bulk box 30 inches deep extend about 6 inches above the water until the top of the box moves below the surface of the water. At this time the unit behavior of the fruit ceases to exist and the apples act more like a film of oil on water, in that they spread out into a single layer at the water surface.

A diagram of the unloading machine is shown in Fig. 1. The final design utilized a pneumatically operated carriage for vertically lowering the box of fruit in the tank (Fig. 2) and a wood roll conveyor for removing the fruit from the water and delivering it to the dryer (Fig. 3). The water in the tank was circulated to carry the fruit from the box to the conveyor. A fresh-water spray located above the wood roll conveyor was incorporated to rinse the fruit leaving the machine. A commercial absorber-drier with an air blast was used to remove the excess moisture from the fruit.

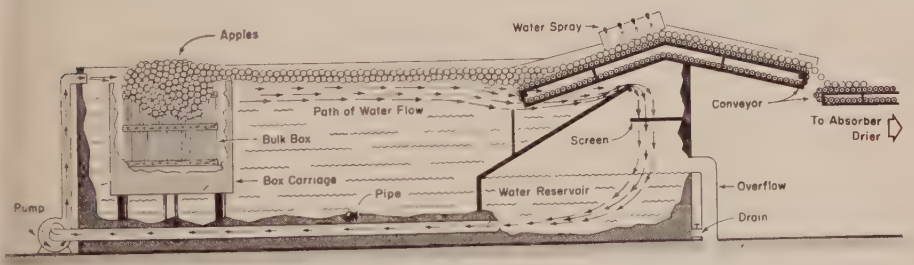

Fig. 1. Cross sectional diagram of unloading machine.

To date, no tests have been conducted where the excess moisture is removed from the fruit using a blower directly over a wood roll conveyor; however, since the fruit normally has a good coat of wax, it appears that there is a good possibility that this is all the water removal that is necessary.

[3]Smock, R. M. and A. M. Neubert (1950). *Apples and Apple Products.* Interscience Publishers Inc., New York City.

The bulk box submergence carriage shown in Fig. 2 is powered by two 5-inch bore, 48-inch stroke pneumatic cylinders. The carriage was fabricated from sheet metal to minimize weight; 3-inch standard black pipe was used to make the legs. The wood 3 x 6's at the bottom inside of the carriage (Fig. 2) were replaced with nylon-bushed roller conveyor track when this machine was installed in the packing line.

The conveyor for removing the apples from the tank was constructed of No. 55 agricultural chain with 2 5 8-inch wood rolls on

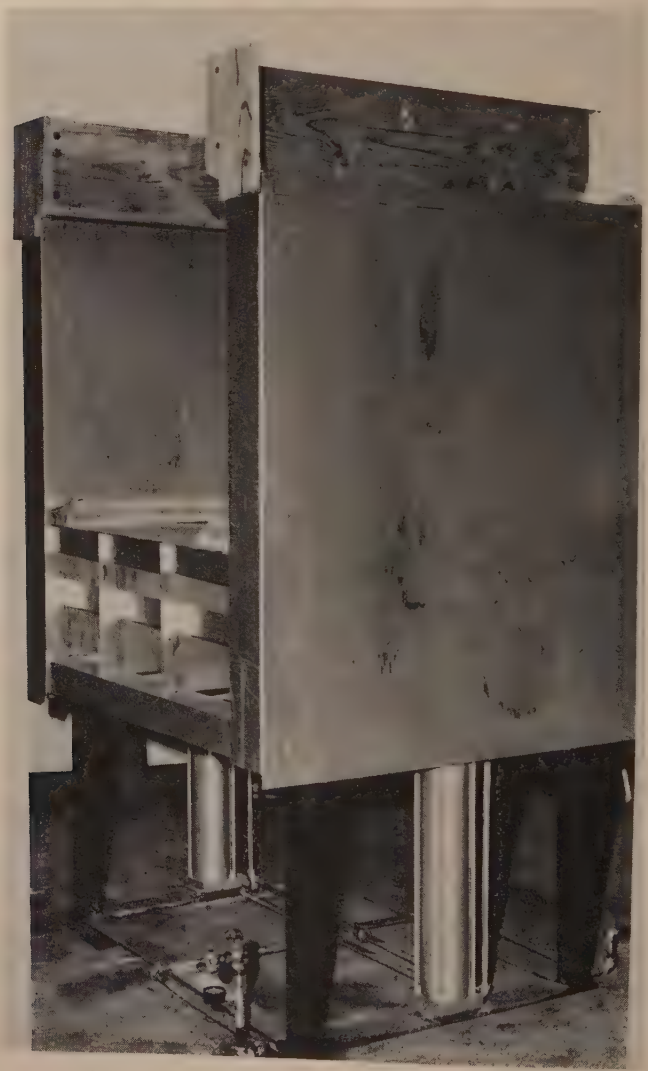

Fig. 2. Bulk box submergence carriage.

Fig. 3. Top view of unloading machine showing conveyor at end of water tank, fresh water sprays above conveyor and water flow pattern across the top of bulk box.

every other link (3 ¼ inches O. C.). The rolls were supported by hardwood boards; therefore, the rolls and fruit rotated as the conveyor advanced. Experiments were conducted using large apples to determine the conveyor angle. An angle of 17° was found desirable for the conveyor elevating apples out of the tank; however, the angle of the down side of the conveyor had to be reduced to 12½° to keep the apples from tumbling (angles are measured from the horizontal). The conveyor was 3 feet wide and 10 feet long; approximately 250 in. lb. of torque was required to start the conveyor.

The water tank width of 54 inches and depth of 72 inches were fixed by the dimensions of the submergence carriage. The length of the water tank was determined by the capacity of the grading line and

the time necessary to change boxes since the area between the submergence carriage and the conveyor was for holding fruit to feed the grading line, while the empty box was removed and the full box moved into position.

The packing line had a design capacity of 300 bushel per hour (5 bu. per min.). It was estimated that 2 min. would be required from the time a box was empty until the next box was supplying fruit. Therefore, space in the machine for 10 bushels of fruit was required. Initial calculations were made assuming one crowded layer of apples in this area. It was found in practice that the apples will make a 4- or 5-inch deep layer if slightly crowded. A 20 ft. long tank was selected to satisfy these requirements.

A water reservoir was incorporated into the machine as shown in Fig. 1. Water from the reservoir tank was pumped to the box unloading end of the machine by a 5 HP centrifugal pump, capacity 500 gpm at 25 ft. head, where it was directed along the surface by a series of nozzles. The water flowed from the nozzles to the weir at the far end of the tank, creating a velocity the entire length of the water surface carrying the apples from the box to the conveyor.

The weir formed by the end of the partition separating the unloading tank from the reservoir maintained an approximately constant water level in the tank, even when a box was rapidly lowered into the water. The water displaced by the bulk box rapidly flowed into the reservoir over the weir that extended the full width of the machine.

The fruit-rinse sprays continuously add fresh-water to the system. Some of this water is needed to replace water carried out by the fruit; the remainder is eliminated by the reservoir overflow.

FRUIT BRUISING STUDIES

Limited tests for mechanical damage of apples handled through the unloader were made in April, 1960 with McIntosh and Golden Delicious apples removed from controlled atmosphere storage. Fruit free of bruises and other mechanical damage were carefully placed, with the aid of a specially constructed crib,[4] into the bottom and top quarter of loaded bulk boxes. Approximately three bushels of McIntosh, averaging 10.3 pounds in firmness, were placed into each of four bulk boxes of Golden Delicious, and a like amount of bruise-free Golden Delicious (firmness, 10.8 pounds) were placed into each of two bulk boxes of McIntosh and two boxes of Red Delicious apples.

[4]Burt, S. W. (1960). Personal correspondence.

The boxes were unloaded during the regular packing operation for the particular variety and the test fruit removed at three points; namely, from the water tank just ahead of the removal conveyor, at the end of the removal conveyor, and upon leaving the drier. These apples were placed into tray-pack cartons, returned to cold storage for one week and then examined for damage.

Bruised fruit were classified as slightly, moderately, or seriously damaged according to the criteria employed by Burt[5] for the McIntosh variety; these degrees of bruising would eliminate fruit from U. S. Extra-Fancy, U. S. Fancy and U. S. No. 1, and U. S. Utility grades, respectively. The number of apples with stem punctures were recorded without regard to bruising. The percentages of damaged apples, according to variety, type, and degree of damage are summarized in Table 1. The values of damage at the end of the conveyor

[5]Burt, S. W. (1959). An experimental packing line for McIntosh apples. U. S. D. A., A.M.S. Report No. 330.

TABLE 1—Average percentage of fruit with bruises and stem punctures after unloading from bulk boxes (values for end of conveyor and end of drier are accumulated damage to that point)

Point of removal	Damage	Variety	
		McIntosh	Golden Delicious
Water	Slight bruising	25.3	18.5
	Moderate bruising	11.1	5.9
	Serious bruising	7.4	1.4
	Total	43.8	25.8
	Stem punctures	4.1	0.9
End of conveyor	Slight bruising	32.0	30.6
	Moderate bruising	12.4	12.4
	Serious bruising	7.4	7.4
	Total	51.8	50.4
	Stem punctures	7.7	0.3
End of drier	Slight bruising	31.0	36.1
	Moderate bruising	27.6	23.8
	Serious bruising	21.4	3.0
	Total	80.0	62.9
	Stem punctures	13.0	1.7

include the damage of unloading as well as conveying; the values of damage at the end of the drier include damage of unloading, conveying and drying.

Less than half of the McIntosh, and approximately one-quarter of the Golden Delicious apples, taken from the water before passing onto the conveyor were damaged. Most of this injury was slight bruising, and could have occurred to a considerable extent in the boxes before unloading. This factor, however, was not determined.

Bruising was increased slightly on McIntosh by passing over the conveyor and almost doubled for Golden Delicious; however, passage through the drier added much bruising to McIntosh and a relatively small amount to Golden Delicious. Further study to ascertain why the several components of the unloading machine cause differences in the amount of damage between varieties is desirable.

Stem punctures were not serious at any point for the Golden Delicious apples. The quantity of stem punctures for McIntosh, after removal from the boxes, was relatively low for this variety; it was approximately doubled by passage over the conveyor, and then almost doubled again through the drier.

The percentages of bruised apples in Table 1 may appear to be large; however, the percentage of apples showing serious bruising is relatively small. The amount of bruising incurred using this water unloader is only a small fraction of the bruising that occurs in a tilting type bulk box dumper.

DISCUSSION OF THE OPERATION

A side view of the machine is shown in Fig. 4. The machine has been fitted with conveyor track so that the tie-up time of the fork lift truck and box-changing time are minimized. In Fig. 4, an empty bulk box is being raised out of the tank, a full box is on the roller conveyor; in Fig. 5, this empty box has been pushed forward, out of the carriage and the full box pushed into the submergence carriage and is on its way down into the water. When the carriage is completely submerged, the empty box will be moved to the extreme right, where the full box is located in Fig. 4, on the conveyor track across the top of the carriage, shown moving into position in Fig. 6.

The pile of dry apples in Fig. 6 is being held out of the water by the apples below it, even though the box is below the surface of the water.

A plug valve was installed in the pump discharge line to permit variation of the water flow during an unloading cycle.

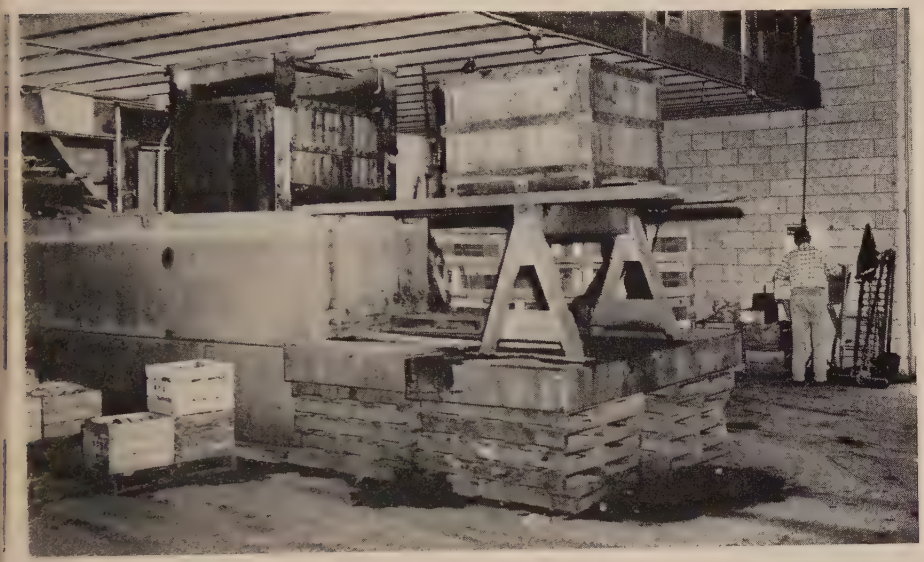

Fig. 4. Empty bulk box being raised out of water, full box is on roll conveyor awaiting unloading.

Fig. 5. Empty box has been removed from conveyor and full box pushed into submergence carriage and is on its way down into the water.

Fig. 6. Top apples (upper center) are lifted several inches out of the water by the buoyant force of the mass of fruit in the submerged bulk box.

This machine was put in use about December 1959, and by the end of the 1959-1960 storage season had been used to unload about 100,000 bushels of fruit. This method and machine have proved to be a satisfactory solution to the problem of removing soft apples such as McIntosh and Golden Delicious from bulk boxes, without excessive mechanical injury.

SUMMARY

The principles of operation and important design features of a machine for unloading bulk boxes of fruit by water floatation and transfer have been described and illustrated. The operating principle on which the design of this apparatus is based has proved to be sound through six months of severe field service. Bruising and skin puncturing of relatively soft apples were not excessive, but improvements in the design of the removal conveyor and drier would further decrease damage.

ACNOWLEDGMENTS

The development of this machine was a co-operative project between Michigan State University and the Belding Fruit Sales Co., Belding, Michigan. The authors acknowledge and thank the several members of the latter organization who suggested and encouraged this project, and then made the prototype machine a commercial success.

The authors appreciate the assistance of J. H. Levin, Agricultural Engineering Research Division, ARS, USDA, who helped in the planning and made valuable suggestions regarding conveyor arrangements.

Special thanks are due Glen Shiffer of the Agricultural Engineering shop who transformed ideas into a workable machine.

THE YIELD OF MAPLE SAP PER TAPHOLE[1]

By PUTNAM W. ROBBINS
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THE VOLUME OF MAPLE SAP OR "sweet water" produced per taphole and the sugar content of that maple sap are of great importance to the sugar bush operator. A knowledge of the yield of sap per taphole would enable the sugar bush owner to more efficiently plan his sirup production from the standpoint of determining the number of buckets to hang, the size evaporator to purchase, the volume of fuel to provide, and the labor necessary to operate the sugar bush.

Unfortunately, there is little accurate data available on the yield of maple sap per taphole or per bucket. The older maple sirup bulletins presented the yields by volume per **tree**, which has been somewhat confusing as the number of tapholes or buckets per tree varies with the diameter of the tree. The accepted rule is to hang one bucket on trees 10 to 15 inches in diameter, two buckets on trees 15 to 20 inches, three buckets on trees 20 to 25 inches and four buckets on trees over 25 inches in diameter.

The sugar content of maple sap has been ably presented by Taylor (13) who reported from a survey of 4,500 trees that maple trees have a wide variation in the sugar content of their sap. Trees in the same sugar bush may vary as much as 2 to 3 percent in the sugar content of their sap. Taylor (13) also found that a single tree will show variation in the sugar content of sap from one season to the next. However, a tree producing a high sugar content is generally consistently high.

The sugar content of maple sap may be readily determined with the aid of a "Brix" sap hydrometer, or a refractometer. However, a refractometer is too expensive to recommend to the average maple sirup producer. It is possible after repeated tests during a season and successive seasons, to screen all trees in the sugar bush according to the sweetness of their sap, and eliminate the low producers.

[1]Funds for this project were provided under a research and marketing act contract, with the U. S. Department of Agriculture, Agricultural Research Service, Philadelphia, Pa.

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To determine the total maple sirup or sugar potential of a taphole, the total flow of sap in pounds or gallons must be known. A taphole producing 3 percent sugar as solids in its sap will produce 3 pounds of sugar for every 100 pounds of maple sap. The simplest method is to use the "Rule of 86" (15). Maple sirup of standard density (65.5 degrees Brix) contains 86.3 percent of solids (as sugar) on a weight volume basis. The density of maple sap being comparatively low, its Brix value and percentage of solids (weight-volume) are essentially the same.

Therefore, the percentage of solids (weight-volume) of the sirup divided by the Brix value of the maple sap equals the number of gallons of sap required to produce 1 gallon of finished sirup. For example, a taphole producing sap of 3 percent sugar (86 divided by 3 equals 28.7) the approximate number of gallons of this sap to produce 1 gallon of finished sirup. Therefore, it is essential to know the yield of maple sap per taphole in gallons, as well as the sugar content, if the sugar bush is to be operated in the most efficient manner.

The maple sap or "sweet water" yield from maple trees was reported at an early date (1885) by Dr. H. A. Cutting (5), when he recorded the gram weights of sap from 15 tapholes for one season. The sap volumes varied from 297 to 77,863 grams per taphole. On the average converted to gallons this would give a yield of approximately 6.5 gallons per hole. Jones, Edson, and Morse (7) in 1903 reported an average of approximately 4.3 gallons, but unfortunately they do not state if this included the entire season's sap flow.

Fox and Hubbard (6) in 1905 reported a yield of 19 gallons of sap per tree during eight consecutive seasons, including one poor season. However, they do not state the number of buckets or tapholes per tree. Collingwood and Cope (4) in 1938 reported the yield per taphole to be 15 gallons, but they present no data as to the number of tapholes, seasons or measurements to support their figure. McIntyre (8) in 1932 reported the yield from over 400 tapholes averaged 25 quarts (6.25 gallons) per hole. Anderson, Ball, Moore and Baker (1) reported yields of 5.35 to 14.03 gallons per bucket for Ohio. Tressler and Zimmerman (14), during a three-year period, reported the yield from 258 tapholes averaged 9.6 gallons.

The author (12), during a three-year study of maple sap flow and weather relationships at the Dunbar Forest Experiment Station, Chippewa County, Michigan, weighed the flow of maple sap from 25 tap-

holes on 25 trees every day of flow and found the average to be 12.8 gallons per taphole.

The author also reported (11) that the yield of sap from 359 tapholes in the Michigan State University demonstration sugar bush at East Lansing, over a five-year period, 1933 to 1938, averaged 9.7 gallons per taphole. Morrow (10) in a study of tree crowns in relation to sap production reported yields of 13 gallons per bucket for trees with typical woods crowns, 16 gallons for trees growing in semi-open conditions, and 24 gallons per bucket for roadside trees. Willits (15), in one of the most complete and recent publications on maple sirup, states the yield per taphole ranges from 5 to 15 gallons.

A maple sap research project to study many phases of maple sirup production was conducted by the Forestry Department of Michigan State University in cooperation with the Eastern Utilization Research and Development Division of the Agricultural Research Service of the U. S. Department of Agriculture, Philadelphia, Pennsylvania. It afforded an excellent opportunity to accurately determine the flow of maple sap and the sugar content of the sap from individual tapholes.

The trees tapped in this project are located in one of the sugar maple woodlands on the university campus. The "Baker" woodland of 70 acres was selected in preference to the 55 acre "Sanford" sugar bush, which has been operated as an experimental and demonstration sugar bush since 1915, because the trees in the "Baker" woodland had never been tapped. Therefore, this woodland would give data which could not be influenced by previous tapping operations. The trees were tapped for the first time in February 1953, during the 48-hour period before the first sap run. This is forecast to the Michigan maple sirup producers by the Michigan Section of the U. S. Weather Bureau and the Forestry Department of Michigan State University over radio station WKAR.

All maple sap was weighed to the nearest tenth of a pound during every day of flow, and the sugar content of the sap was taken at the same time with a hand refractometer. All measurements were transferred to IBM cards and the summaries were produced by the machines.

Table 1 presents the data on year of tapping, number of trees tapped, number of tapholes, total yield in gallons for the season, yield per taphole, average sugar content of the sap and the yield of sugar in pounds, and the total number of weights taken on which the yields were based. Only the tapholes, which were not influenced by other

TABLE 1—Number of trees, tapholes, yields of sap and sugar per taphole, and number of weighings

Year	Trees tapped	Number tapholes	Total yield gal. sap	Yield taphole gals.	Av. sugar content of sap	Yield pounds sugar taphole	Basis no. of wts.
1953.....	72	120	1,713	14.3	2.98%	3.5	2,802
1954.....	72	120	2,750	22.9	2.19%	4.2	4,755
1955.....	122	170	3,612	21.2	1.88%	3.3	5,419
1956.....	102	150	2,674	17.8	2.40%	3.5	4,635
Four year average.	92	140	2,687	19.05	2.38%	3.62	4,403

treatments conducted during the project, were used for the data in Table 1.

The four-year average yield of 19 gallons of maple sap per taphole as given in Table 1 is considerably greater than the yields reported by Jones, Edson and Morse (7) of 4.3 gallons of sap; Collingwood and Cope (4) of 15 gallons; McIntyre (8) of 6.25 gallons; Anderson, Ball, Moore and Baker (1) of 5 to 14 gallons; Tressler and Zimmerman (14) of 9.6 gallons; Morrow (10) of 13 gallons for woods trees; and the author (11) of 9.7 gallons of maple sap per taphole.

This good yield of 19 gallons per taphole for four seasons with an average sugar content of 2.38 percent, if converted to maple sirup by the "Rule of 86" would require only 36 gallons of sap to produce 1 gallon of finished sirup, i.e., (86 divided by 2.38 equals 36.1). Therefore, this yield would produce approximately ½ gallon of maple sirup per taphole, which is more than double the yields of maple sirup per taphole (0.12 to 0.27 gallons) previously reported by the author for 14 seasons (12). It is also greater than the 0.32 gallons of sirup per bucket for woods trees as reported by Morrow (10).

This yield of 3.62 pounds of sugar per taphole as given in Table 1 is greater than the maximum reported per **tree** for any one year of 30 years of maple sirup crop reporting (16) by the Bureau of Agricultural Economics, Crop Reporting Board, U. S. Department of Agriculture.

This high yield demonstrates the potential production of maple sirup possible from a managed woodland which has never been pastured and one that has received periodic harvest and improvement cuttings aimed primarily for the production of lumber.

LITERATURE CITED

1. Anderson, W. R., J. S. Ball, H. R. Moore, and Richard Baker (1949). Factors influencing yield and cost of maple sirup. Ohio Agr. Expt. Sta., Farm and Home Research, Vol. 34 (256): 10-12.
2. Barraclough, K. E. (1952). Maple sirup and sugar production in New Hampshire. Univ. of N. Hampshire, Ext. Bul. 103, 28 pp., illus.
3. Bryan, A. Hugh, and W. F. Hubbard, (1924). Production of maple sirup and sugar. U. S. D. A. Farmers' Bul. 1366. 35 pp., illus.
4. Collingwood, G. H. and J. A. Cope, (1938). Maple sugar and sirup. Cornell Univ. Bul. 397, 32 pp., illus.
5. Cutting, H. A., (1885). Vermont Agr. Dept., Chemical Div., Bul. 6, 208 pp.
6. Fox, W. F. and W. F. Hubbard, (1905). The maple sugar industry. U. S. D. A., Bur. of Forestry Bul. 59, 59 pp., illus.
7. Jones, C. H., A. W. Edson and W. J. Morse, (1903). The maple sap flow. Vt. Agr. Expt. Sta. Bul. 103, 144 pp., illus.
8. McIntyre, A. C. (1932). The maple products industry of Pennsylvania. Penn State College, School of Agr. and Expt. Sta. Bul. 280, 47 pp., illus.
9. Moore, H. R., W. R. Anderson and R. H. Baker (1951). Ohio maple sirup. Ohio Agr. Expt. Sta. Res. Bul. 718. 53 pp., illus.
10. Morrow, R. R. (1955). Influence of tree crowns on maple sap production. Cornell Univ. Agr. Expt. Sta. Bul. 916. 30 pp., illus.
11. Robbins, P. W. (1948). Position of tapping and other factors affecting the flow of maple sap. Mich. State Univ. Forestry Dept., Thesis, M.S. degree, 35 pp., illus.
12. _____, (1949). Production of maple sirup in Michigan. Mich. Agr. Expt. Sta. Circ. Bul. 213. 28 pp., illus.
13. Taylor, F. H. (1956). Variation in sugar content of maple sap. Univ. Vt. & State Agr. Col., Agr. Expt. Sta. Bul. 587, 39 pp., illus.
14. Tressler, C. J. and W. I. Zimmerman (1942). Three years' operation of an experimental sugar bush. New York State Agr. Expt. Sta. Bul. 699, illus.
15. Willits, C. O., (1958). Maple sirup producers' manual. U. S. D. A. Agr. Handbook 134. 80 pp., illus.
16. U.S. Department of Agriculture (1946). 1946 Maple Products. Bur. of Agr. Economics, Crop Reporting Board.

FOLIAR DAMAGE TO HOTHOUSE GROWN RHUBARB FROM SULFUR DIOXIDE FUMES

By HOWARD S. POTTER and HARRY H. MURAKISHI

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A NUMBER OF INSTANCES of injury to the leaves of hothouse grown rhubarb from an unknown cause were reported in Macomb County, Michigan during 1958 - 1959. Investigation of forcing houses where the damage occurred revealed that growers were using coke or soft coal for heating. Sulfur dioxide fumes were very noticeable and in some cases the fumes made it impossible to remain in the houses for any length of time. Humidity in these forcing houses was 90 percent or higher and the temperatures ranged between 60 - 65° F. During colder weather, condensation occurred on the leaves. Analysis of the condensed liquid showed that it contained dilute amounts of sulfuric acid, indicating that the sulfur dioxide escaping from the heating system was combining with the atmospheric moisture. As atmospheric conditions changed, evaporation of water from the leaf surface occurred, leaving droplets of concentrated acid. These would collect at the base of the blade where the leaf has a tendency to cup.

The caustic action of the acid caused the leaf tissue to turn brown, become dry and paper-like and eventually fall out, giving the leaf a perforated, torn appearance (Fig. 1). Acid damage can easily be confused with the leaf damage resulting from the foliar feeding of cut worms.

To avoid the problem, growers should make certain that pipe sections in all coal or oil fired heating units are sound and properly fitted at the joints. Good air circulation and adequate ventilation, preferably of the forced draft type, will prevent accumulation of fumes escaping accidentally and will also aid in maintaining a lower humidity in forcing houses.

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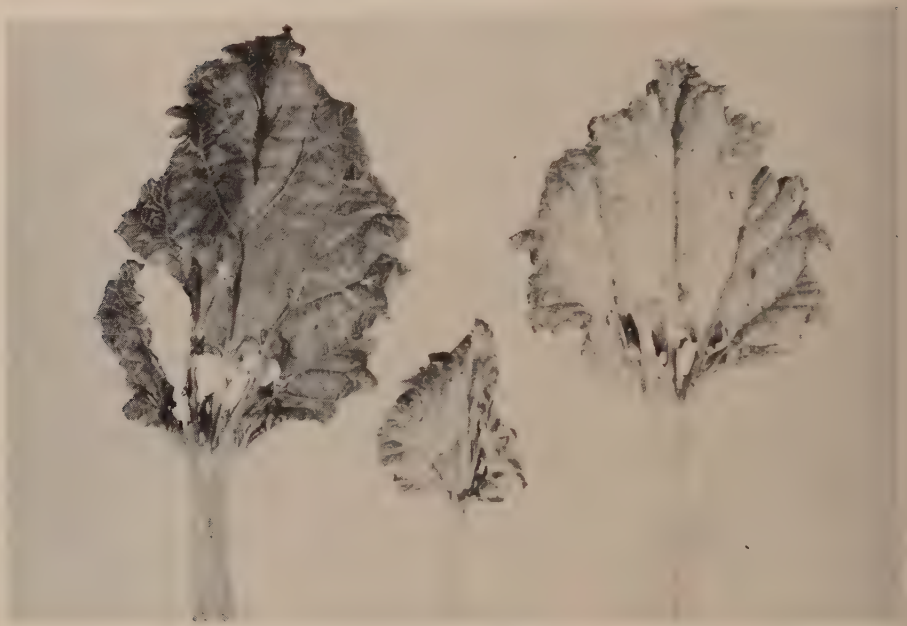

Fig. 1. Leaves of hothouse grown rhubarb showing chemical injury resulting from the release of sulfur dioxide fumes from coke fueled heating stoves.

ACCEPTANCE OF APPLES BY A TASTE PANEL AS RELATED TO CHEMICAL COMPOSITION

By NORMAN HARRIS and A. L. KENWORTHY

Department of Horticulture

Fruit quality is a relatively intangible factor for which no reliable index has been developed. Such indices as ground color, firmness, seed color, skin color, soluble solids, taste, etc. are helpful in evaluating quality at harvest and shortly thereafter but are not reliable as a measure of quality changes that occur after the fruit is removed from storage and held for consumption.

Upon removal from storage, a given lot of fruit may have maximum acceptance or maximum acceptance may be attained after a few days of higher temperatures. Chemical changes are greatly accelerated when fruit is removed from storage and held at temperatures commonly found on the sales counter.

This study was made to explore the possible relationship of certain chemical changes after storage to acceptance as measured by sensory evaluation.

PROCEDURE

The apples were stored at 32° F. for one month after harvest. When removed from storage the apples were held for none, three, and six days in respiration containers at 75° F. for measurement of CO_2 evolution. A modification of the colorimetric method, devised by Claypool and Keefer (1942), was used for CO_2 evaluation. Following the respiration measurements, each lot of apples was divided into two lots. One lot was prepared for analysis to determine pectin fractions, reducing and non-reducing sugars, and titratable acidity.

Pectin analysis was made by use of the method of Luh et al (1954). Sugars and titratable acidity were determined by procedures of the Association of Official Agricultural Chemists (A.O.A.C.) and Sell et

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al (1956). The other lot was used for sensory tests conducted in a manner similar to that of Wright and Whiteman (1955).

A panel of 11 students and faculty members evaluated texture, taste, and flavor-aroma. Each lot of apples held at none, three, and six days at 75° F. was replicated three times, making a total of 27 decisions by the panel members and 33 judgments on texture, taste, and flavor-aroma characteristics.

RESULTS AND DISCUSSION

The rating scale or points for each sensory test is shown in Table 1, which also gives the frequency of choice by panel members as multi-

TABLE 1—Sensory tests, points and score, for Golden Delicious apples held for 0, 3, and 6 days at 75° F.

Sensory test	Points	Frequency of choice x points(a)		
		0 days	3 days	6 days
Texture				
Hard	15	0	0	15
Firm	25	100	50	50
Crisp	30	420	330	330
Soft	20	280	380	300
Mealy	10	10	10	40
Total	..	810	770	735
Taste				
Starchy	5	5	10	30
Sour	10	40	20	30
Tart	30	480	330	210
Sweet	25	100	275	175
Low sugar/acid	10	80	70	100
Total	..	705	705	545
Flavor-aroma				
Lacking	15	165	90	180
Approaching optimum	35	350	210	105
Optimum	40	240	240	240
Past optimum	30	60	360	180
Insipid	10	20	20	30
Stale	0	0	0	0
Total	..	835	920	635
Total sensory score	..	2,350	2,395	1,915

(a) Totals for three replicate samples. Dividing these values by the point score results in frequency of choice.

plied by the point score as a measure of quality. The lowest total score was given to those apples held for six days at 75° F. Taste characteristics were lowest for apples held six days at 75° F. and similar for apples held none and three days. The highest total score for flavor-aroma was given to the apples held three days at 75° F. and lowest score to those held six days.

Statistical analysis did not show any significant differences in acceptance of apples from the three holding periods. The sensory scores for individual characteristics showed no general relationships to time held at 75° F., except for a general decrease in tartness. The scores indicate the apples immediately out of storage were below optimum for flavor-aroma while those held for six days were past optimum.

Holding apples in respiration chambers at 75° F. for none, three, and six days resulted in certain changes in CO_2 evolution and chemical composition as shown in Table 2.

TABLE 2—Respiration rate, pectin, sugar and titratable acidity analysis of Golden Delicious apples as related to period held at 75°F.

	Days in respiration chambers		
	0	3	6
Respiration rate (mg/kg for 1 hr.)	50.8	31.2	24.0
Pectin (mgm/100 gm)			
Water soluble	570.6	558.9	405.8
Oxalate soluble	605.8	867.5	748.3
Acid soluble	645.9	958.4	556.3
Total	1,822.3	2,384.8	1,710.4
Sugars (%)			
Reducing	15.7	14.5	17.2
Non-reducing	1.9	2.0	3.1
Total	17.6	16.5	20.3
Acidity (meq./100 gm)	5.5	4.7	4.6
Sugar/acid ratio	3.2	3.5	4.4

Rate of respiration showed a decrease with increased time at 75° F. The most rapid decrease occurred within three days and after six days was approximately one-half that found at no days. Of the pectin

fractions, water soluble pectin was the only one that showed a direct relationship (a decrease) with time held at 75° F. Oxalate soluble, acid soluble and total pectin were highest for apples held for three days and lowest for apples held for six days at 75° F.

Non-reducing sugars increased with longer holding at 75° F. Reducing sugars and total sugars were highest for those apples held for six days and lowest for those held for three days at 75° F. Titratable acidity decreased as the apples were held for longer periods at 75° F. The sugar/acid ratio increased as the apples were held at 75° F. for longer periods.

A comparison of the data presented in Tables 1 and 2 shows possible relationships between certain sensory values and chemical analysis. The total sensory score appeared to be related to total pectin and acid soluble pectin and inversely related to reducing sugars and total sugars.

The sensory tests for texture appeared to be related to respiration rates, water soluble pectin, non-reducing sugars, titratable acidity and sugar/acid ratio. A decrease in the sensory test for texture was associated with a decrease in respiration rates, water soluble pectin and acidity, but with an increase in non-reducing sugars and the sugar/acid ratio.

The sensory tests for taste showed no general relationship to the chemical analysis. Tartness appeared to be related to titratable acidity and the sugar/acid ratio. Sweetness appeared to be related to oxalate soluble pectin and not directly related to sugar content or sugar/acid ratio.

Sensory tests for flavor-aroma were related to the total pectin and acid soluble pectin fractions and inversely related to reducing sugars and total sugars.

It would not be possible at this time to predict that similar relationships would hold for other varieties. Without doubt, the chemical factors associated with the various sensory characteristics would vary with the variety and be dependent upon the general characteristics of each variety.

SUMMARY

Golden Delicious apples were held in cold storage at 32° F. for one month after harvest. The apples were then placed in respiration chambers for none, three, and six days at 75° F.

After determining the rate of CO_2 evolution the apples were used

for chemical analysis and sensory tests. The results indicated that certain chemical constituents may be related to sensory scores and suggest the possibility of developing a more reliable test than visual techniques to determine shelf life or acceptance of apples by the consumer.

ACKNOWLEDGMENTS

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LITERATURE CITED

Claypool, L. L. and R. M. Keefer (1942). A colorimetric method for CO_2 determination in respiration studies. Amer. Soc. for Hort. Sci. Proc. 40: 177-186.

Luh, B. S., S. Leonard, and W. Dempsey (1954). Pectic substances of Pearson and San Marzano tomato. Food Research. 19: 146.

Official Methods of Analysis. 8th Edition. Association of Official Agr. Chemists. 544-45. Box 540, Ben Franklin Station, Washington 4, D. C.

Ibid. 354.

Sell, H. M., F. A. Johnston, and F. S. Lagassee (1956). Changes in chemical composition of the tung fruit and its component parts. Jour. Agr. Res. 73: 319-334.

Wright, R. G. and T. M. Whiteman (1955). Some changes in eastern apples during storage. 17. Tech. Bull. 1120. U.S.D.A.

WINTER RUNOFF FROM SNOW AND FROZEN GROUND

By LLOYD L. HARROLD and ROY L. ROBERTS, JR.[1]

WATERSHED MANAGEMENT PROGRAMS in northern areas of the United States are complicated in the winter season by snow and frozen ground. Frost in the soil may often determine whether melting snow or rain will become direct runoff—available for water supply and possibly for contribution to floods, or whether it will be absorbed into the soil mantle for future crop growth and recharge of groundwater.

Effective planning for programs of watershed protection, improvement of water supply, and erosion and runoff control requires a knowledge of the effect of various cover conditions on frost depth and permeability, and consequent runoff. On large watersheds of complex soil and land use, the inter-relationships between the many factors associated with winter runoff are extremely involved. Data from small watersheds, of single land use and more uniform soils provide a means for study and isolation of the relationships among the factors.

In 1940 a research project,[2] designed to study and evaluate the important factors in snow and frozen ground hydrology, was established at Michigan State University at East Lansing, Michigan. Two cultivated watersheds were instrumented on lands of the University, and one wooded watershed at the nearby Rose Lake Wildlife Experiment Station. Each of the watersheds is about two acres in area. Recording instruments were installed to obtain data on precipitation, runoff, air temperature, relative humidity, soil temperature, soil moisture, and solar radiation. Manual observations were made periodically to determine snow depth, water equivalent, and frost penetration.

This report includes data and discussion for only the cultivated watersheds, data for these watersheds being more complete than for

[1]Project Supervisors, respectively, of Soil and Water Conservation Research Stations, ARS, Coshocton, Ohio, and East Lansing, Michigan.

[2]Cooperative project of the Soil and Water Conservation Research Division, ARS, USDA, and the Michigan Agricultural Experiment Station.

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the wooded watershed. The aspect of the two cultivated watersheds is N-NW. The average slope of watershed A is 6 percent, and that of watershed B is 6.5 percent. The soils of the watersheds are well drained and of glacial origin.

Eighty percent of the soils of watershed A are Spinks fine sandy loam and loamy fine sand, and 20 percent are Hillsdale fine sandy loam. Ninety-one percent of the soils of watershed B are Spinks fine sandy loam and loamy fine sand, and 9 percent are Tuscola fine sandy loam. The surface drainage of both watersheds is good. Both watersheds were basically in a rotation of corn with cover crop, oats, and two years of hay. A map of the cultivated watersheds is shown in Fig. 1 and a general view of the area is shown in Fig. 2.

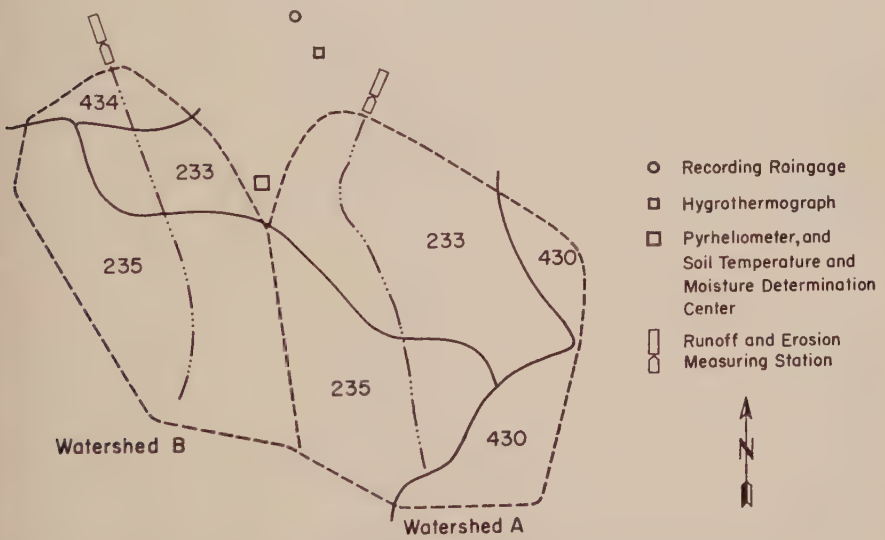

Fig. 1. Map of the watersheds. Soil Legend: 233 Spinks fine sandy loam. 235 Spinks loamy fine sand. 430 Hillsdale fine sandy loam. 434 Tuscola fine sandy loam.

RECORDS AVAILABLE

A detailed examination of the records showed that quite complete data on the winter hydrology of the two watersheds were available for the six-year period beginning in the fall of 1946 and ending in the spring of 1952.

Precipitation data are from a USWB Type standard rain gage located as shown in Fig. 1. Data from a recording rain gage and a Nipher type shielded standard rain gage are also available. Rainfall

Fig. 2. General view of the watersheds showing the flume on Watershed A and the large shelter that houses the recorder for the pyrheliometer, and soil temperature and moisture determination center.

data are reliable, however the snowfall data, as measured by the rain gage, must be used with caution. It is well known that ground drifting and air currents cause substantial error in measurements of snowfall with rain gages.

Snow depth and snow water content data are from periodic snow surveys. These were made with a Mount Rose snow tube, taking 28 samples in each watershed. The 28 samples included four taken on each of five evenly spaced traverses across the width of the watershed, and eight on a diagonal traverse. Snow depth was computed as the average depth of the 28 samples. The composite of all 28 samples, melted and measured in the tube of a standard rain gage is the depth of snow-water storage on the watershed (the area of a standard rain-gage is 28 times the area of the Mount Rose tube.) The estimates of snow depth and water content are considered to be reasonably reliable.

Frost depths were measured by use of Bouyoucos gypsum electrical resistance blocks. Though installed for measurement of soil moisture, some difficulty was experienced in the winter periods in obtaining soil moisture measurements. However, the block installations did operate remarkably well as indicators of frost depths – upon

freezing the electrical resistance of the blocks increases tremendously. The blocks were installed at depths of ½, 1, 3, 6, and 9 inches for the period ending April 1949, and at 3, 6, 12, 24, 36, and 60 inches for the remainder of the period.

Temperatures of the soil, used primarily to adjust the resistance readings of the gypsum blocks, were obtained by thermohms. It was apparent early that soil temperatures were not an accurate indicator of frozen ground. With the equipment as described, it was possible only to identify the depth of frozen soil as being at the various depths at which blocks were placed. Within these limits, the data on depths of frost are believed to be reliable.

Air temperature was measured by a recording hygrothermograph located in a large instrument shelter as shown in Fig. 1. The calibration of the temperature record is checked with a maximum and minimum thermometer which is read daily.

Solar radiation was measured with an Eppley 10-junction thermopile, thermo-electric pyrheliometer mounted atop a small instrument house. The data are reported in "Langleys"; one Langley is an amount of radiant energy equal to 1 gram-calorie per square centimeter. Data for the period of record are believed to be reliable.

Runoff was measured with a type 3-H metal flume and automatic stage recorder. The floor and stilling wells of the flume were electrically heated to prevent the formation of ice; thus winter runoff records, for the most part, are reliable.

Several of the items of data, including the soil moisture block observations, soil temperatures, and solar radiation were carried by electrical leads to the small shelter house and automatically or manually recorded. A section of the instrument panel in the shelter house is shown in Fig. 3. A more complete discussion of the instrumentation of the watersheds has been published by Gartska.[3]

Observations of type, condition, and yields of crops were also made. The winter cover conditions for the period are given in Table 1. Further information on the condition of winter cover is given with the graphical presentations.

PRESENTATION OF DATA

In this region the monthly runoff is higher during the winter season than in the other seasons. Monthly runoff data for these

[3]Garstka, W. U. (1944). Hydrology of small watersheds under winter conditions of snow cover and frozen soil. Amer. Geop. Union, Trans. Part VI pp. 838-871.

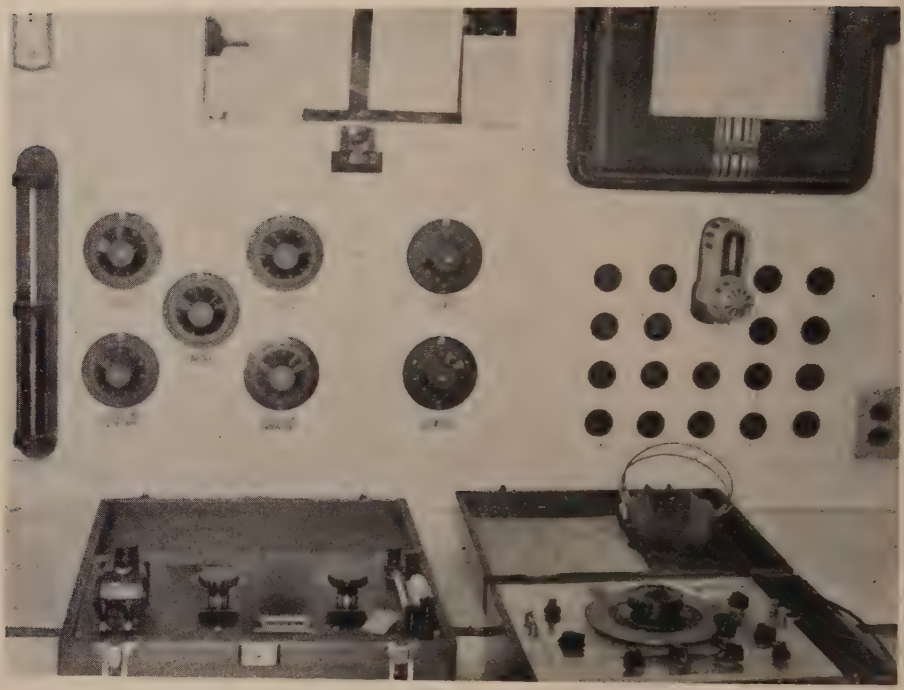

Fig. 3. Instrument panel in the shelter house. The five large switches on the left connect the portable potentiometer, lower left, to the different soil temperature units. The two large center switches and the 18 small switches at the lower right connect the soil moisture bridge to the soil moisture blocks at the different depths. The recording potentiometer, upper right, gives a continuous record of solar radiation.

watersheds for the period 1942-55, as compiled by the Agricultural Research Service as a working tool, substantiate this fact. It is common, however, for the greatest flood peaks from small cultivated areas to occur in the summertime.

As shown in Table 2, over 90 percent of the average annual run-

TABLE 1—Winter cover conditions

Year	Watershed A	Watershed B
1946-47	Rye and corn stalks	Alfalfa
1947-48	Alfalfa-brome and oat stubble	Rye and corn stalks
1948-49	Alfalfa-brome	Rye and corn stalks
1949-50	Alfalfa-brome	Alfalfa-brome and oat stubble
1950-51	Rye and corn stalks	Alfalfa-brome
1951-52	Rye and corn stubble	Alfalfa-brome

TABLE 2—Average monthly runoff from cultivated watersheds, 1942-55

Month	Watershed	
	A(*a*)	B(*b*)
	Inches	Inches
January	0.45	0.45
February	1.48	1.01
March	1.52	1.57
April	.24	.13
May	.09	.06
June	.10	.12
July	.01	.01
August	.05	.05
September	.08	.07
October	.01	0
November	0	0
December	.12	.09
Year's total	4.15	3.56

(*a*) 1.98 acres of well-drained sandy loam, average slope 6 percent.
(*b*) 1.35 acres of well-drained sandy loam, average slope 6.5 percent.

off occurred during the five-month period of December through April. An examination of the daily data for this season in each year was deemed a necessary step in the evaluation of their significance for detailed hydrologic analyses.

Graphs were therefore prepared for six winter seasons for which data were complete. These begin with the winter season of November 1946 through April 1947 (Fig. 4) and end with that of November 1951 through April 1952 (Fig. 9). The graphs include, in order from the top of the graph:

1) Daily amounts of rainfall as measured by the recording rain gage. Snowfall as measured by the rain gage is not included.
2) Snow depth and water content of the snow on the watersheds. Snow depths appear as separate lines for the two watersheds whenever the values differed; likewise the water content of the snow stored on the two watersheds appears as separate symbols when the values differed.
3) Frost depths in the soil as determined by the soil moisture blocks. Where the depths of frost in the two watersheds differed, separate lines are shown. Thawing of the frozen soil downward from the surface is shown by shaded intrusions.

These graphs show sudden changes of several inches in frost depths from one day to another. It is likely that these changes occurred more gradually. For example, observations from soil moisture blocks on a series of days may have indicated frost at the 6-inch depth but not at the 9-inch depth. On the next day after the series, the 9-inch block may have shown the presence of frost. So all that could be shown graphically is a frost depth increase from 6 inches to 9 inches in one day. The frost depth, however, could have been increasing gradually over a period of several days. Occasionally, block observations showed frost at a certain depth on one day, an increase of several inches on the next day, and a return to the first depth on the following day and for several days thereafter. In such instances, the isolated one-day value was not used.

4) Runoff amounts from each watershed. Usually these are daily amounts, but when runoff was observed for two or three consecutive days, the total for the period is shown.

In every year, there was at least one period of special interest—when the runoff from the watersheds was clearly influenced by various combinations of several factors. These periods, referenced at the bottom of Figures 4 through 9, have been selected for more detailed graphical presentation.

In the graphs of Figures 10 through 17 the more detailed information provides a basis for studying the major factors associated with winter runoff. The graphs include, in order from the top of the graph:

1) Daily amounts of precipitation, in inches. Rain and snow are shown separately. The amounts are those recorded by the rain gage. A rain gage, however, does not always provide an accurate measurement of snowfall.
2) Daily amounts of runoff, in inches, as measured with the flumes.
3) Air temperature in terms of accumulated degree-days below 32° F. This is based on the average of the maximum and minimum observations for the day. The curve of degree-days slopes upward when the temperature is below freezing, and downward when the temperature is above freezing. The slope of the curve is steeper as the temperature deviates farther from 32° F. The steepness and length of an upward segment of the curve defines the severity of a cold period and, conversely, the mag-

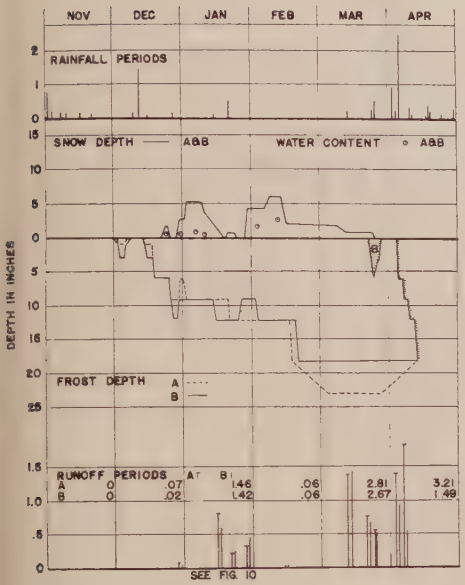

Fig. 4. Summary of frozen ground and snow hydrology, November 1946 through April 1947.

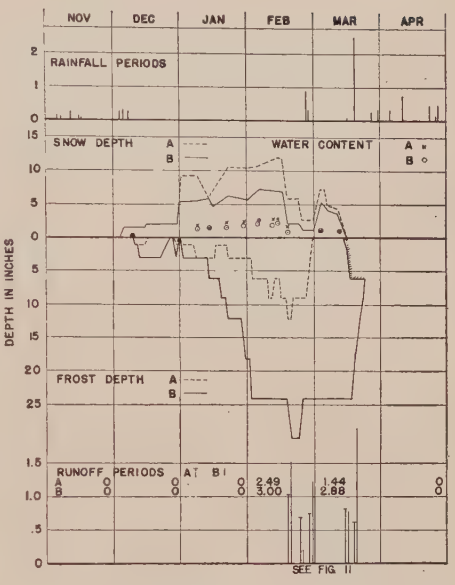

Fig. 5. Summary of frozen ground and snow hydrology, November 1947 through April 1948.

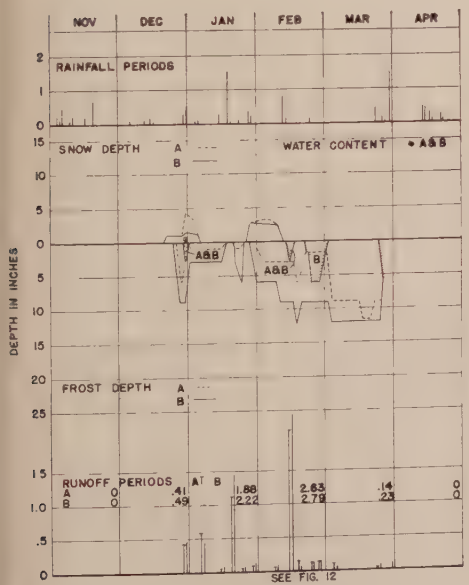

Fig. 6. Summary of frozen ground and snow hydrology, November 1948 through April 1949.

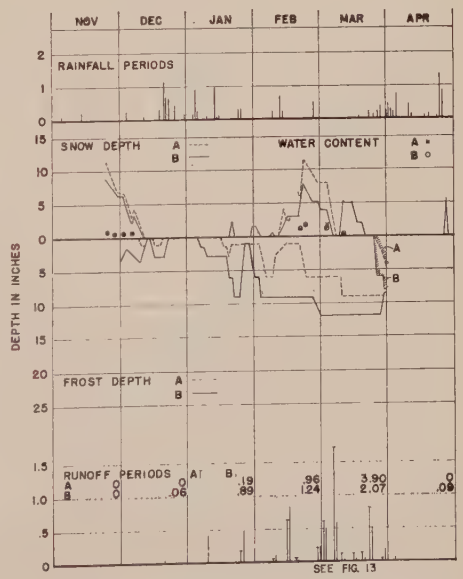

Fig. 7. Summary of frozen ground and snow hydrology, November 1949 through April 1950.

nitude of a warming trend is shown by the steepness and length of a downward segment of the curve.

4) Solar radiation in accumulated Langleys.
5) Snow on the ground in terms of inches of snow-water storage. (In Fig. 17, snow depth is given in terms of inches of snow.)
6) Frost depth, in inches of frozen ground. Thawing from the surface downwards is again indicated by shading.

The title of the figure briefly describes the cover on the watershed.

DISCUSSION

During most winter periods, snow accumulated and melted several times. Sometimes the snow melt produced little or no runoff. More often, it caused runoff. At times, rain fell during the period of snow melt and caused runoff. Such conditions are pointed out in the following discussion of each season of record.

1946-47 winter season:

Figure 4 indicates a period of snow melt following January 9, 1947. The detailed graph of this period (Fig. 10) shows a warming trend from January 13 with runoff from both A and B on January 14. The amount of runoff from A was 0.8 inch and from B, 0.6 inch. Rain totaled only 0.1 of an inch. Measured snow-water storage prior to the melt was 0.6 inch. Soil on both watersheds was frozen to a depth of 10 inches.

The frozen soil on alfalfa-brome watershed B must have been somewhat porous as about 0.1 inch of water (snow melt or rainfall) was absorbed. On watershed A there apparently was 0.1 inch more runoff than water available. This points up the difficulty that is encountered in the measurement of snow-water storage and snowfall.

Similar details could be prepared for a period in early April of the same year (Fig. 4) when over 2½ inches of rain fell on partly thawed soil. Runoff from A (corn stubble with rye winter cover) was about 1.8 inches at that time, compared with less than 0.6 of an inch on B (alfalfa-brome.)

1947-48 winter season:

In the winter period 1947-48, the snow came early in December and stayed until the spring thaw (Fig. 5.) For much of January and about half of February 1948, the snow depth on watershed A (alfalfa-brome) was 10 inches, with a water content of 2.7 inches. Snow depth on watershed B (rye and corn stalks) was about 7 inches, with a water

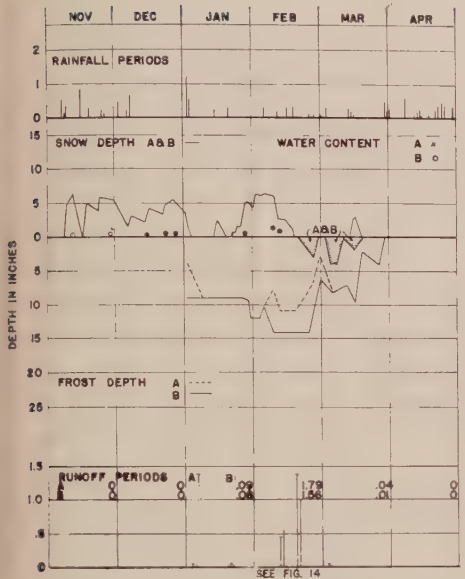

Fig. 8. Summary of frozen ground and snow hydrology, November 1950 through April 1951.

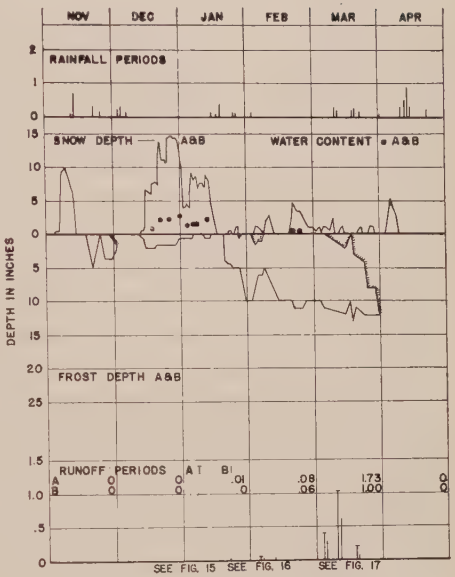

Fig. 9. Summary of frozen ground and snow hydrology, November 1951 through April 1952.

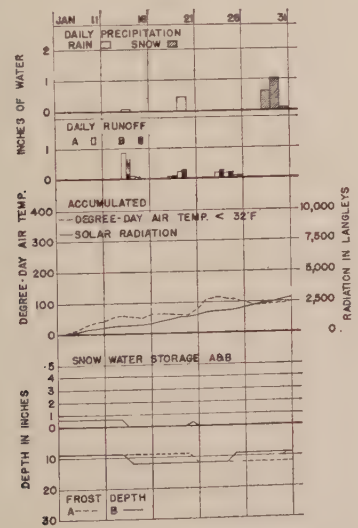

Fig. 10. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, January 8-31, 1947 for Watershed A in rye and corn stubble and B in alfalfa-bromegrass.

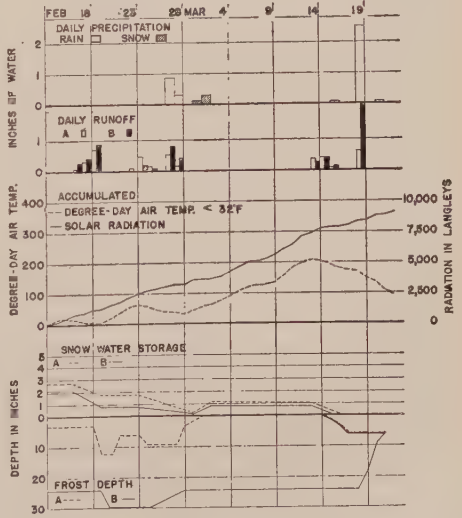

Fig. 11. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, February 14 through March 22, 1948 for Watershed A in alfalfa-bromegrass and B in rye and corn stubble.

content of 2.1 inches. Frost penetrated to a depth of 9 inches on watershed A and to a depth of 24 inches on watershed B during this period. There was no run-off prior to February 16.

The warming trend February 16-19 (Fig. 11) resulted in some melting of snow and a measurable amount of runoff. Runoff from watershed B (1.6 inches) was greater than on A (1.1 inches.) The cold trend February 20-22 stopped the runoff. Another warming trend for the six days following caused snow melt and runoff of 1.4 inches on both watersheds. Rain also contributed to runoff in this period. At the same time, frost diminished without surface thawing from 9 inches to zero on A, but remained at a 24-inch depth on B.

The warming trend of March 14-21 (Fig. 11) removed all the snow and frost from watershed B. Watershed A soil was not frozen during March. Early in the warming period, while B was frozen and A was not, there was 0.8 inch runoff from both watersheds. The rain of March 19 fell on unfrozen soil in watershed A, and on a 0-6 inch thaw over a 6-18 inch frost zone in watershed B. Runoff from A was about 0.6 of an inch and from B, over 2 inches.

1948-49 winter season:

The winter of 1948-49 (Fig. 6) was marked by short periods of snow cover and intermittent frost and thaw. Rain fell on (1) snow cover as it melted on frozen ground, (2) frozen ground without snow cover, (3) on frozen ground with thawed surface, and (4) on unfrozen ground — the whole gamut of winter watershed conditions.

The detailed presentation of data for this season (Fig. 12) shows the February 9—March 5 period with frozen ground and no snow. Most of the runoff during this period was from two rains, February 12 and 14. The soil on both of the watersheds was frozen and the amounts of runoff were quite similar. Rainfall of February 12 totaled 0.82 inch. Runoff for February 12-13 amounted to 1.41 on A and 1.53 on B. The snow survey on February 4 indicated there was 0.23 inch of water on A and 0.16 on B. Gaged snowfall on February 6 was 0.09 inch of water and February 10 was 0.03. Runoff on the 8th and 9th from melting snow was 0.05 inch on A and 0.11 on B.

The overall picture for this period shows runoff to have exceeded the gaged supply by about ½ inch. The only explanation seems to be that the rain gage did not record all of the snowfall. It is a notoriously-poor snow gage. The best record of snow-water storage is that obtained from the field sampling.

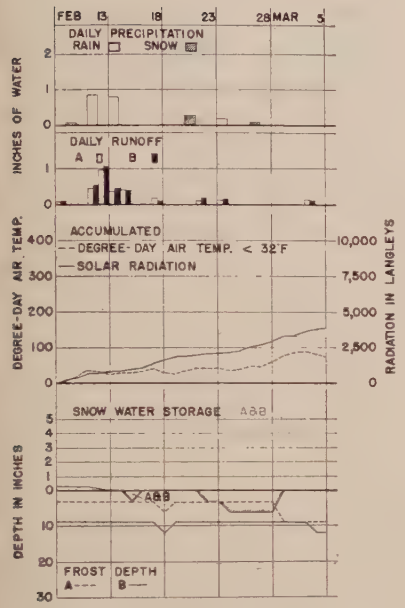

Fig. 12. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, February 9 through March 5, 1949 for Watershed A in alfalfa-bromegrass and B in rye and corn stubble.

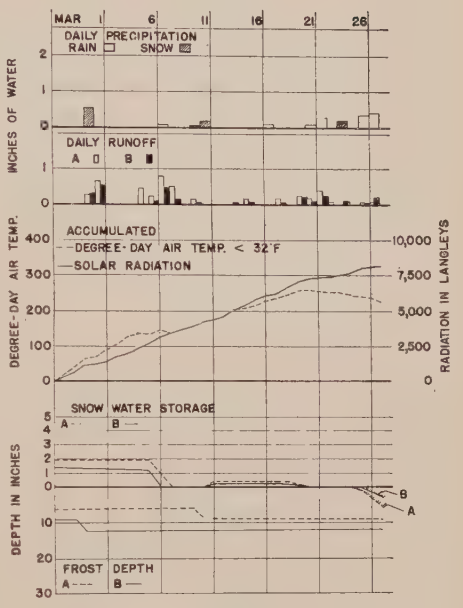

Fig. 13. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, February 25 through March 27, 1950 for Watersheds A and B in alfalfa-bromegrass.

The rain of 0.78 inch on February 14 resulted in 0.76 inch runoff from watershed A and 0.80 inch from B. There was no snow on the watersheds during this runoff period, the soil was frozen, and there was practically no infiltration.

The surface soil on both watersheds thawed to a depth of 2 to 3 inches on February 15 and then refroze. From February 23 to 28, the soil on B watershed thawed to a depth of 6 inches. February 28 to March 3, a cold wave caused the soil to refreeze and the frost to go deeper.

This season, rain fell twice on unfrozen ground with contrasting results. On January 18-19, 1949, 1.53 inches of rain mixed with sleet fell. The runoff from A was 1.11 inches and from B, 1.43 inches. And, on March 31, 1949, 1.55 inches of rain mixed with snow fell with no runoff from A and only 0.09 inch from B. The soil moisture content on both dates was similar.

1949-50 winter season:

In the 1949-50 winter season (Fig. 7), runoff occurred numerous times. Rains in late December, falling on unfrozen ground, caused practically no runoff. Snow depth and snow-water storage on both watersheds were much the same. Rains during January, February, and March, falling on frozen ground, caused frequent runoff.

Rains during April, on unfrozen soil, resulted in practically no runoff. The detailed presentation of frozen ground (Fig. 13) covers the period February 25-March 27, 1950. A snow-storage of 1.2 to 1.9 inches of water disappeared in about two days. The greater amount of snow-water occurred on the surface of watershed A (2nd year alfalfa-brome), and its runoff from March 5-8 of 1.9 inches was also greater than the 0.6 inch from watershed B (1st year alfalfa-brome.)

1950-51 winter season:

Runoff in the 1950-51 winter season (Fig. 8) was confined mostly to the mid-February period of snow melt and rainfall (Fig. 14.) The

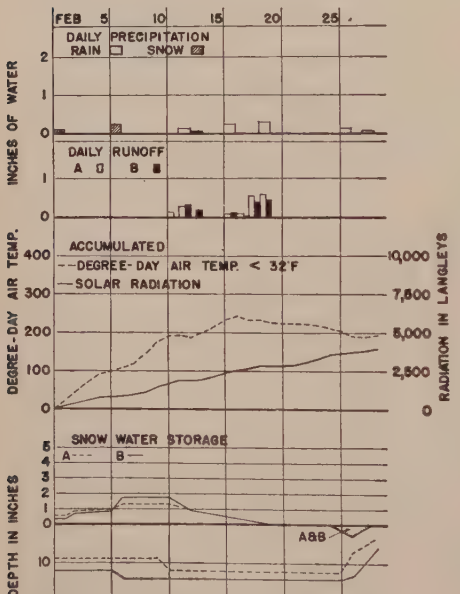

Fig. 14. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation and resultant runoff, February 1-28, 1951 for Watershed A in rye and corn stubble and B in alfalfa-bromegrass.

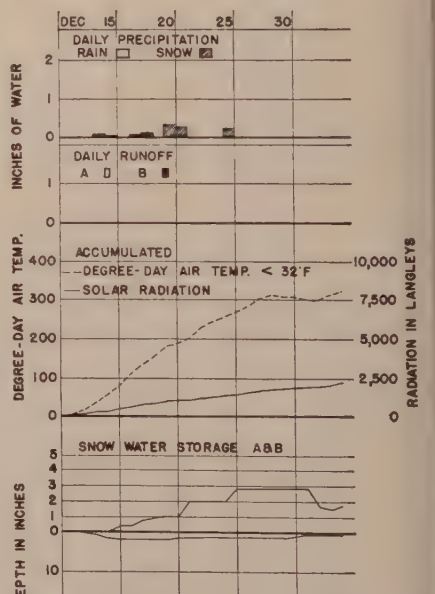

Fig. 15. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, December 11, 1951 through January 3, 1952 for Watershed A in corn stubble and B in alfalfa-bromegrass.

water equivalent of the snow on February 10 for watershed A was 1.3 inches and for B was 1.7 inches. By February 19, it was all gone. In the period February 10-22, 0.8 inches of rain fell. The total supply of water in the 12-day period was 1.3 + 0.8 = 2.1 on A and 1.7 + 0.8 = 2.5 inches on B.

Runoff for the period from A totaled 1.8 inches and from B, 1.6 inches. By subtraction of runoff from supply, an approximate evaluation of infiltration and evaporation can be obtained. For A it would be 2.1 — 1.8 = 0.3 inch and for B, 2.5 — 1.6 = 0.9 inch. At this time, watershed A had a land cover of rye and shredded corn stover and watershed B, a cover of second-year alfalfa-brome.

1951-52 winter season:

The 1951-52 winter period (Fig. 9) was marked by its wide variety of conditions. The 10-inch snow that fell on unfrozen ground early in November melted in a few days. Rain fell on the last 2 days of this melting period, yet there was no runoff. Snow accumulation in December reached a depth of nearly 15 inches on A and 14 inches on B. Maximum water equivalent of the snow on A was 2.8 inches and on B, 2.3 inches. Since snow data on A and B were almost the same, separate lines on Fig. 9 were not practical.

December 11-28 (Fig. 15) was marked by a long period of cold weather. The temperature curve ascends steeply and continuously for 18 days. In that period, 312 degree-days of air temperature below freezing had accumulated. Although the average daily temperature was more than 17 degrees below 32° F. for the period, the frost zone in the soil was shallow—2 inches and less for both watersheds. After the first four days of the period, a snow mantle of 5 to 15 inches in depth probably helped to prevent further penetration of frost. Solar radiation for the 18-day period totaled 1620 Langleys. This is not an exceptionally high value. By January 17, the snow had completely melted without runoff.

The soil on both watersheds began to freeze again on January 21 (Fig. 16) and reached a maximum depth of 10 inches by January 31. Snow cover was shallow and intermittent. There were no rains of consequence during this period. Runoff was very slight.

Rains in March were greater. The soil was partly thawed on top and snow depth was still of minor importance. Runoff resulted from rainfall as shown in detail on Fig. 17.

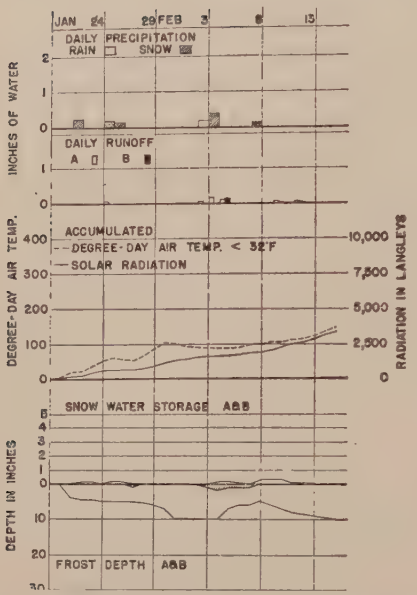

Fig. 16. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, January 20 through February 15, 1952 for Watershed A in corn stubble and B in alfalfa-bromegrass.

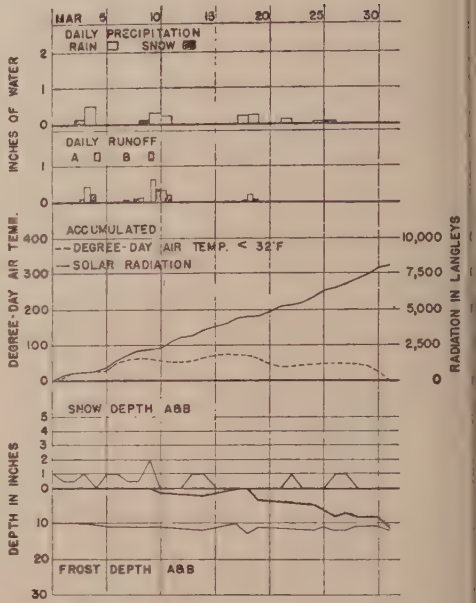

Fig. 17. Details of frost depth, solar radiation, air temperature, snow-water storage, precipitation, and resultant runoff, March 1-31, 1952 for Watershed A in corn stubble and B in alfalfa-bromegrass.

SUMMARY

In 1940 a research project, designed to study and evaluate the important factors in snow and frozen ground hydrology, was established at Michigan State University, East Lansing, Michigan. Two cultivated watersheds (discussed in this report) were extensively instrumented on University land, and one wooded watershed at the nearby Rose Lake Wildlife Experiment Station.

The area of each of the three watersheds is about two acres. The aspect of the two cultivated watersheds is N-NW. The average slope of watershed A is 6 percent, and that of watershed B is 6.5 percent. The soils of the watersheds are well-drained fine sandy loams and loamy fine sands and of glacial origin. Both watersheds were basically in a rotation of corn with cover crop, oats, and two years of hay.

The data and discussion in this report constitute only a simple graphical presentation of basic summaries of some measured factors which are believed to influence precipitation-runoff relations during

periods of freezing and thawing of the soil mantle and accumulation and melting of snow. It is clearly apparent, however, that the relationships among the factors shown on the graphs are not simple.

It is possible that there are unknown and unmeasured factors that would help to explain some of the phenomena. It is possible that the precision of the measurements was not sufficiently refined to allow rigorous analysis of the relationships involved. The runoffs that occurred on January 14, 1947 and February 12-13, 1949 indicate the difficulties that are encountered in the measurement of snow-water storage and snowfall. At both times the runoff was greater than the indicated available water.

Differences that seem to be explained by one variable (cover) are shown by the runoffs of April 5, 1947. On that date, over 2.5 inches of rain fell on a thawed surface underlain with frozen soil on both watersheds. Runoff from A (corn stubble with rye winter cover) was about 1.8 inches, compared with less than 0.6 inch on B (alfalfa-brome.) March 19, 1948 indicates the effect of two variables (cover and occurrence of frost.) The soil on watershed A (alfalfa-brome) was not frozen, but on watershed B (corn stubble with rye winter cover) there was a surface thaw underlain with frozen soil. A rain of 2.5 inches caused a runoff from A of about 0.6 inch and from B, over 2 inches.

January 18-19, 1949 and March 31, 1949 point to the effect of some unmeasured factor. In January, over 1.5 inches of rain and sleet fell with runoffs from both watersheds of over 1 inch, but in March, over 1.5 inches of rain and snow fell with no runoff from A and very little from B. On both dates the soil was not frozen and the soil moisture content was similar.

Though some of the measured factors, such as solar radiation and soil temperatures have been individually described and studied in some detail by Crabb[4] and Crabb and Smith,[5] no complete analysis of all the measured factors has yet been attempted. Special attention is now being given to the comprehensive interpretation of the temperature, solar radiation, frost zone, runoff and other related data collected at the East Lansing project over the years. Efforts are also being made, in continuing the data collection activities, to record the various factors with more precision and with better continuity.

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[4]Crabb, George A., Jr., (1950). Solar radiation investigations in Michigan. Mich. State Univ. Tech. Bul. 222.

[5]_____, and James L. Smith (1953). Soil-temperature comparisons under varying covers. Highway Research Board Bul. 71, Washington, D. C., pp. 32-80.

POULTRY SCIENCE RESEARCH AT THE UPPER PENINSULA EXPERIMENT STATION

Chatham, Michigan

I. The Engineering and Cost Aspects of the Basic Structure of Five Types of Poultry Houses

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FOUR EXPERIMENTAL POULTRY HOUSES, each measuring 36′ x 54′, were constructed during the summer of 1957 at the Upper Peninsula Poultry Housing Project at Chatham, Michigan. The structural cost analysis presented here is based primarily upon information derived from the Upper Peninsula project. The initial costs of the four houses are compared with house No. 5 which has been constructed on a number of Michigan farms. Each house consisted of a different type of construction identified by the following:

1. Insulated Frame.
2. Baled Straw-Pole Frame.
3. Gothic Roof Frame.
4. Concrete Block.
5. Insulated Pole Frame. (M.S.U. Plan No. 727-C1-87).

The four experimental poultry houses are shown in Fig. 1 during the latter stages of construction in the late summer of 1957. For purposes of identification, they have been numbered from the left to the right as shown in Fig. 1, and from north to south as oriented on the site. It will be noted that there is a partially completed structure between Houses 3 and 4. This is a utility building constructed with a stud frame wall, clear-span wood roof trusses and with the same dimensions (36′ x 54′) as the poultry houses.

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ARTICLE 43-20

Fig. 1. The four experimental poultry houses at the Upper Peninsula Experiment Station, Chatham, Michigan, summer 1957.

Total Cost of Buildings

The total cost of the five buildings constructed for this project was $30,625.32. The five buildings, including the utility building, have a floor area of 1944 sq. ft. each, a total of 9,720 sq. ft. This makes the average first cost of these structures $3.15/sq. ft.

These cost figures include the leveling of site, concrete footings for four buildings, concrete under the dropping pits, complete concrete floor for the utility building, building materials, four bulk feed-bins, (3-ton capacity each) a six-inch well, a submersible pump, water under pressure to each house, plumbing, electrical wiring, oil-fired hot water boiler for heating the utility building and to provide supplemental heat to House No. 4, and labor.

The breakdown of costs for the five buildings was 55 percent for materials and preparation of site, 15 percent for utilities, and 30 percent for labor. The framing materials included considerable native wood dimension lumber at $95/M bd. ft. (thousand board feet), which offsets, to some extent, high prices paid for commercial lumber and concrete caused by freight charges for these latter materials to the Upper Peninsula of Michigan. The Chatham Experiment Farm is somewhat isolated from ready-mix concrete plants; therefore, $589.90 was required for just the delivery of concrete.

The labor was supplied by a crew of six Michigan State University students under the direct supervision of staff members of the Poultry Science and Agricultural Engineering Departments.

House No. 1—Insulated Frame

The structural details of House No. 1 are shown in Figs. 2 and 3. This structure has a stud frame wall which sets on a concrete block foundation and supports a clear-span wood truss roof.

The foundation consists of six courses of 8″ concrete blocks placed on a reinforced concrete footing 8″ x 16″ in cross section. The walls are insulated with 2″ x 24″ fiber glass blanket. An additional sheet-type vapor barrier was placed over the stud framing prior to installing vertical board interior sheathing. The roof construction was ring-bolt, clear-span wood trusses spaced 4′ on center (M.S.U. Plan No. 703-C1-64). A ceiling of ⅝″ CD plywood was installed with 8″ of shavings placed above for insulation. Fig. 3 presents a detailed cross sectional drawing of House No. 1.

Fig. 2 shows two 4″ riser pipes coming out of the floor. The electric wires and plastic water pipe were placed in a single 4″ fiber

Fig. 2. The insulated frame house (No. 1) during construction: Ring-bolt clear span roof trusses, blanket wall insulation, plywood bulk feed bin and utility lines.

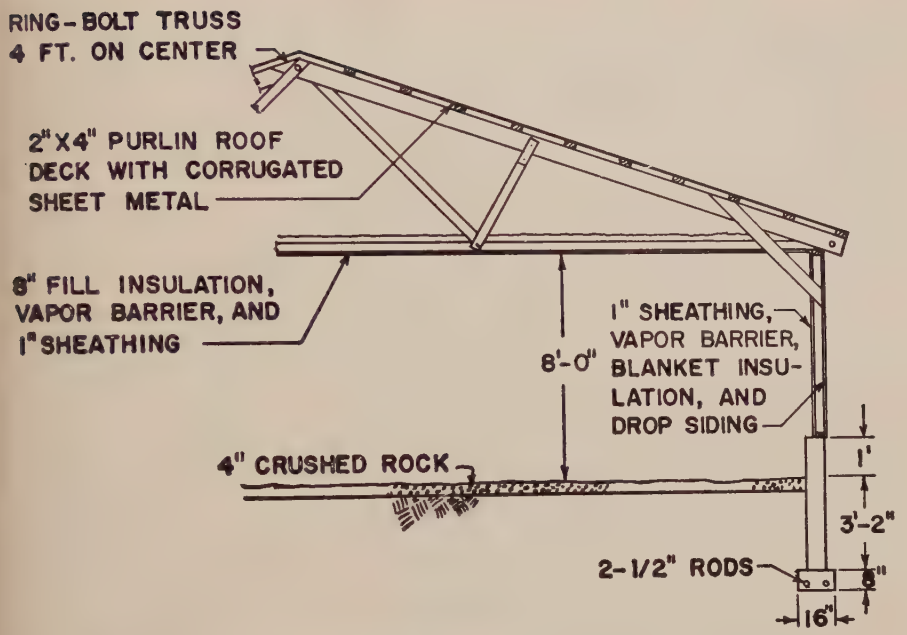

Fig. 3. Cross section view of the insulated frame house (No. 1).

pipe for the horizontal runs below ground and brought up to the surface separately.

Each building was supplied with a 4′ x 4′ x 16′ plywood bulk feed bin as shown in Fig. 2. These 3-ton capacity bins were constructed on the site and included in the total building costs.

House No. 2—Baled Straw-Pole Frame

The unique feature of this house was the baled straw sidewalls, as illustrated in Fig. 4. The baled straw served as insulation as well as interior and exterior sheathing. The structural frame of this house was a typical pole design, as shown in the detailed sectional drawing of Fig. 5. The sidewall poles were spaced two bale lengths apart and the sill below the bales consisted of two treated planks.

A poultry netting ceiling supported insulation consisting of a minimum of 2′ of straw after settling. This type of construction represented a minimum material cost for insulation and interior and exterior sheathing.

Fig. 4. The baled straw, pole frame house (No. 2) showing side wall construction of baled straw.

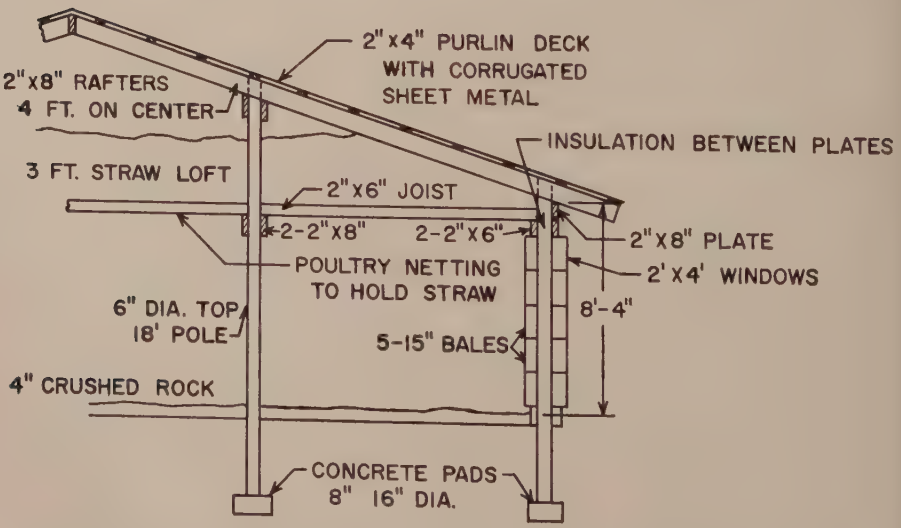

Fig. 5. Cross section view of the baled straw, pole frame house (No. 2).

House No. 3—Gothic Roof Frame

The "arch" or "gothic" roofed building constructed with laminated members has been a popular type of farm building construction in Michigan. Fig. 6 shows the arch frame completed and end sections being constructed. Fig. 7 is a detailed sectional drawing of the building design.

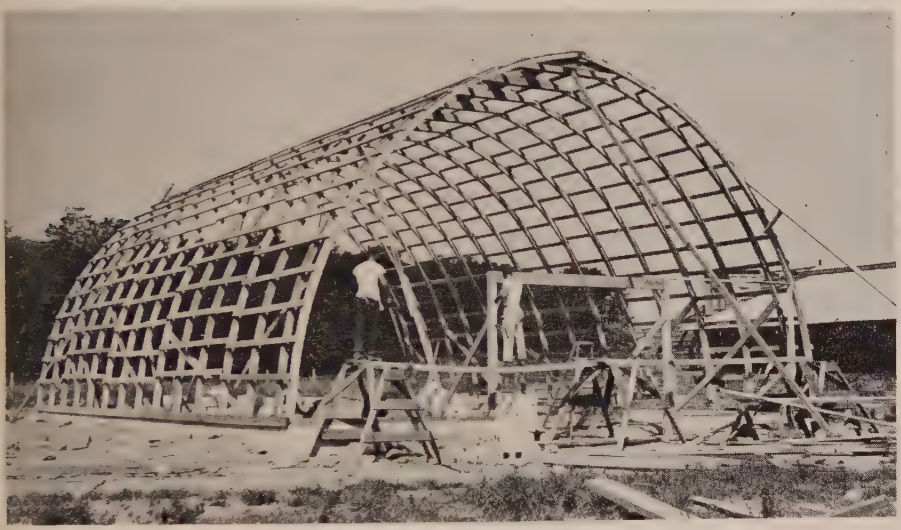

Fig. 6. The gothic roof frame house (No. 3) showing the laminated wood arches erected into position after being prefabricated on the ground.

The arch ribs were fabricated on the building site. They consisted of five 1″ x 4″ members glued and nailed together. A grade A, airplane-type casein glue was used. The arched members were fabricated in a jig, taken out immediately and allowed to cure a minimum of two days in temperatures above 75° F.

This type of construction provides sufficient volume for a two-story building as shown in the detailed sectional drawing of Fig. 7. The walls were placed on a six-course concrete block foundation similar to that used for the frame building, (House No. 1). Additional piers and posts were required to support the second floor joists. The second floor was designed strong enough for either an additional flock of poultry or for storing materials such as shavings or corncobs, etc., and equipment.

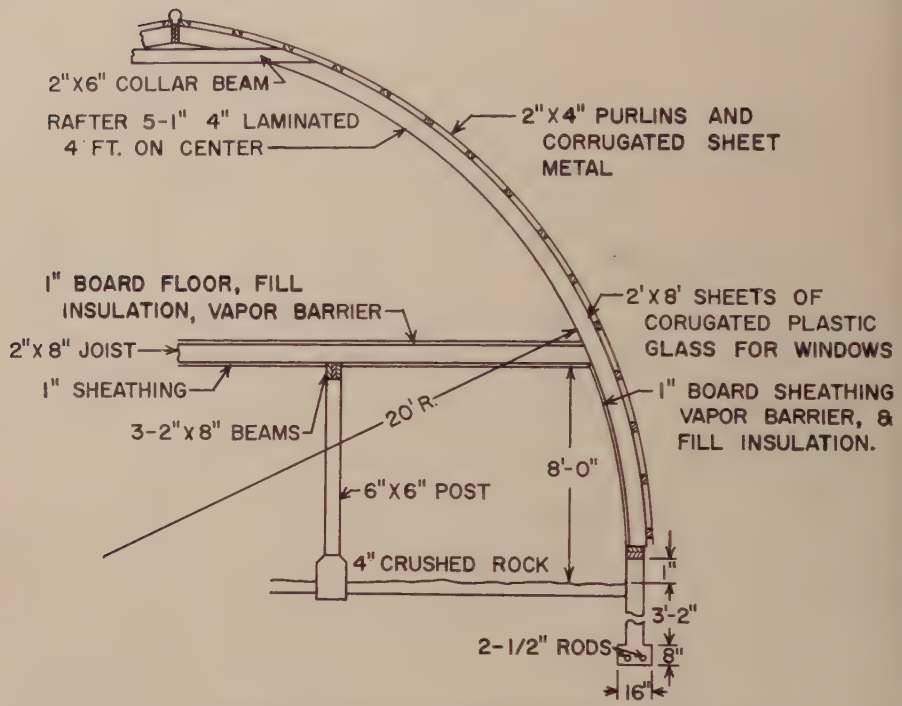

Fig. 7. Cross section view of the gothic roof frame house (No. 3).

House No. 4—Concrete Block

This house was constructed with regular sand and gravel aggregate concrete blocks, as shown in Fig. 8. This type of construction provided much less wall insulation than the insulated frame walls of House Nos. 1 and 3, but from an experimental standpoint, it was desired to test its effectiveness.

A clear-span roof frame of glue-nail wood trusses (M.S.U. Plan No. 703-C1-66) was placed on the concrete block walls. The trusses were spaced 4 feet on center and all members were the same size as the trusses for House No. 1. However, plywood gusset plates, glued and nailed over joints were used, rather than split-ring connectors.

One of the trusses is being placed in position on the wall as shown in Fig. 8. The trusses are first lifted onto the walls in an inverted position and then pivoted into an upright position. A four-man crew can easily do this without special hoisting equipment.

Fig. 9 is a detailed sectional drawing of the concrete block building with clear-span wood trusses. The ceiling was ⅝″ CD plywood and 8″ of shavings for fill insulation was used.

Fig. 8. The concrete block house (No. 4) showing the erection of previously assembled glue-nail, clear-span wood trusses.

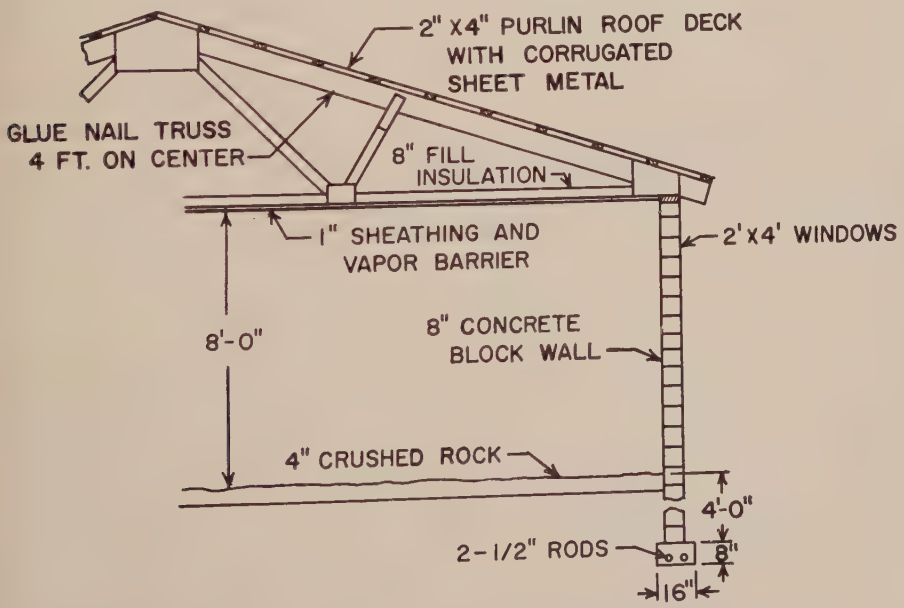

Fig. 9. Cross section view of the concrete block house (No. 14).

House No. 5—Insulated Pole Frame

A poultry house similar to that shown in Fig. 10 was not constructed for this research project; however, it is included in the cost analysis for comparative purposes, inasmuch as it has become a popular plan in Michigan (Plan No. 727-C1-87). This is commonly known as Michigan Tempered Air House. It is noted from Fig. 11 that the wall frame consists of poles 12′ on center with horizontal 2″ x 4″ wall girts inside and out. Blanket insulation, 2″ x 24″ in size, is placed horizontally between the interior wall girts. Interior and exterior sheathing is then placed on the girts.

Fig. 10. An exterior view of the insulated pole frame house (No. 5), M.S.U. plan No. 727-C1-87.

The roof framing consists of clear-span wood trusses spaced 4′ on center. Sheet metal roofing is placed over 2″ x 4″ roof girts spaced 2′ apart. A ceiling of ½″ plywood or 1″ boards is placed below the lower chords of the trusses, and 3″ fill insulation or 3″ blanket is placed above.

Cost Analysis

For an experimental project where different types of housing are being studied under production management, houses 54′ long were justified. However, for normal commercial egg production, houses less than 100′ in length would not be recommended. A 36′ x 100′ house for about 3000 layers is believed to be near the minimum number of layers for which a mechanized poultry house can be practically justified.

In order to make this cost analysis more meaningful and comparable to average-sized houses, the material costs were all pro-

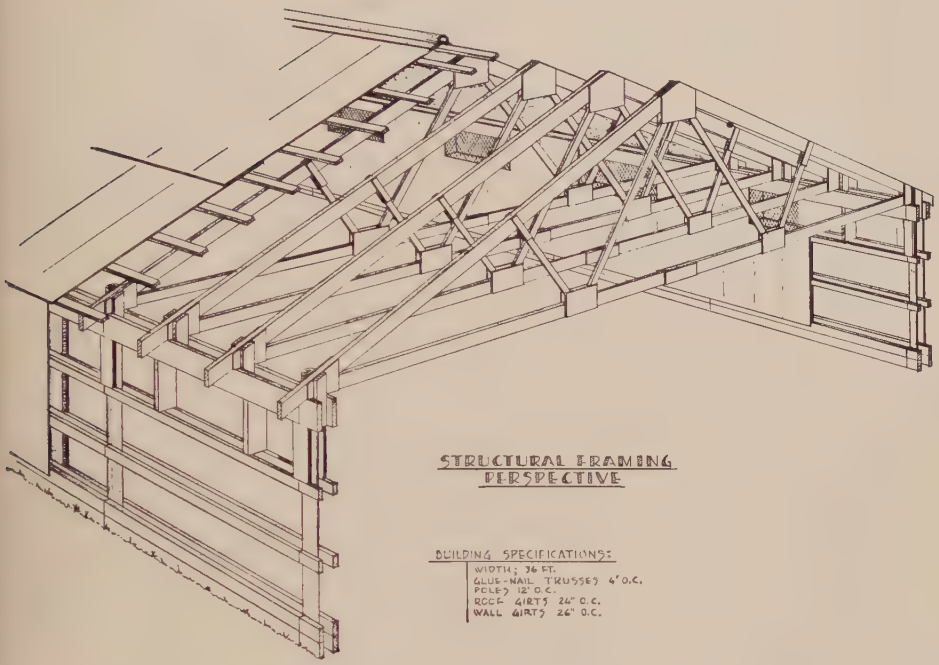

Fig. 11. A structural view of the insulated pole frame house (No. 5), M.S.U. plan No. 727-C1-87.

jected for houses 108′ long. Material costs prevailing for the construction of the experimental poultry houses in the Upper Peninsula during the summer of 1957 were used in this analysis. Any local material prices may be used with the materials lists of Tables 1, 2, 3, 4 and 5 to calculate present building costs in any area for these five types of construction.

The material lists also include unit costs for materials, sub-total and total costs, and costs per sq. ft. of floor area. These tables may also be referred to for detailed specifications of materials used. The total material costs per sq. ft. of floor area for these buildings varied from $1.13 per sq. ft. for the frame house (No. 1) to $.66 for the baled straw house (No. 2).

For a detailed analysis and discussion of the cost of the five types of poultry houses, see Table 6 and Fig. 12, page 185.

Fig. 12 presents graphically the comparative costs of six separate components of poultry house construction. The substructure consisting of foundation and footing was identical for Houses Nos. 1, 3

and 4 and each consisted of six courses of concrete blocks and a reinforced 8″ x 16″ concrete footing. The cost was 14.2 cents per sq. ft. of floor area. Considerable saving in substructure costs are realized with the pole structures of House Nos. 2 and 5, as only the cost of concrete pads under the poles was included. A portion of the poles might well be figured as substructure; however, in this case the total cost was calculated as framing.

The second group of bars in Fig. 12 show the framing costs per sq. ft. to be the lowest for House No. 1. Only wall studs and knee braces were included for this clear-span roof structure. Framing costs for the two pole buildings, Nos. 2 and 5 were higher as this included poles and sidewall girts for House No. 5, and sidewall and interior poles for House No. 2, as well as joist supports and purlins. The framing for

TABLE 1—Costs of frame poultry house, house number 1

Material	Quantity	Unit cost	Subtotal cost	Total cost	Cost per square foot
Substructure					
Footing 8″ x 16″ cont. concrete	10 yards	$16.00	$160.00		
Footing Rein. 2-cont. ½″ rods	576′	.10	57.60		
Foundation 7 concrete blocks	1,512	.22	332.00		
Total for substructure				$549.60	14.2¢
Framing					
Wall and gables (native lumber)	1,701 bd. ft.	95./M	162.00	162.00	4.2¢
Interior Sheathing					
Ceiling—⅜″ CD plywood	3,880 ft.²	180./M	700.00		
Walls—½″ CD plywood	2,304 ft.²	140./M	323.00		
Total interior sheathing				1,023.00	26.4¢
Exterior Siding, 6″ drop siding	3,150 bd. ft.	175.00	550.00	550.00	14.2¢
Vapor Barrier, Plastic Film, 4 mil	6,184 ft.²	.02	119.00	119.00	3.1¢
Insulation, 2″ blanket	5,804 ft.²	47./M	277.00	277.00	7.1¢
Windows, Steel Frame	26	8.00	208.00		
Wood louvers	2	14.00	28.00		
Total for windows				236.00	6.1¢
Doors, 2′-8″ x 6′-8″	2	27.30	54.60		
6′-0″ x 8′-0″	2	18.00	36.00		
Total for doors				90.60	2.3¢
Nails, 16d	25 lbs.	15.00	3.75		
Galvanized nails	75 lbs.	25.00	18.75		
6d	25 lbs.	15.00	3.75		
Total for nails				26.25	.7¢
Roof construction					
Ring Bolt trusses	28 trusses	18.00	504.00		
Roof girts	1,580 bd. ft.	135/M	214.00		
Roofing	45½ sq.	13.70	622.00	1,340.00	34.4¢
Total Materials				$4,373.45	$1.13

TABLE 2—Costs of bailed straw pole-frame house, house number 2

Material	Quantity	Unit cost	Subtotal cost	Total cost	Cost per square foot
Substructure					
Concrete pads 8" thick x 16" diam.	8 yds.	$16.00	$128.00		
Treated sills, 2" x 10"	96 bd. ft.	130./M	12.46		
Total for substructure				$140.46	3.7¢
Framing					
Poles, 42-14', 6-16', 28-18' 6" diameter top	76	3.80	355.20		
		6.00			
Rafter supports (outside) native lumber, 18—2" x 8" x 12'	288 bd. ft.	95./M	27.40		
Window and door framing, native lumber	393 bd. ft.	95./M	37.30		
Total for framing				419.90	10.8¢
Baled Straw—3' x 14"	250	30¢	75.00	75.00	1.9¢
Loose Straw, Straw Loft	14T	15./T	210.00	210.00	5.4¢
Siding for gables	272 bd. ft.	175./M	47.60	47.60	1.2¢
Windows, 2' x 6'	14	2.00	28.00	28.00	.7¢
Wood louvers	2	14.00	28.00	28.00	.7¢
Doors, 2'-8" x 6'-8"	2	27.30	54.60		
6'-0" x 8'-0"	2	18.00	36.00		
Total for doors				90.60	2.3¢
Wire poultry netting for ceiling	3,890 ft.[2]	.10	38.90	38.90	1.0¢
Nails—40d	20 lbs.	17./keg	3.40		
60d	15 lbs.	17./keg	2.55		
20d	27 lbs.	17./keg	5.80		
16d	75 lbs.	15./keg	10.00		
2¼" ring shank head	1 keg	30./keg	30.00		
8d	8 lbs.	15./keg	1.20		
Nail cost total				52.95	1.4¢
Roof Construction					
Framing, native lumber	7,781 bd. ft.	95./M	739.00		
Roofing, corrugated, 28 ga.	4,970 ft.[2]	13.70/M	680.00		
Ridge roll	108 ft.	.22	23.70		
Total for complete roof				1,442.70	37.2¢
Total Materials				$2,574.11	$0.66

the concrete block house (No. 4) was comparably high, as this included the concrete block sidewalls.

Sheathing, interior plus exterior, may account for one-third or more of the total cost of a poultry house. This component of cost for House No. 1 was particularly high, as 5/8" plywood was used on the ceiling and ½" plywood was used on the sidewalls, costing $180/M and $140/M, respectively. Exterior 6" siding, costing $175/M, was used. House No. 5, having a pole frame, has the same interior and exterior areas to cover; however, more practical materials were calculated as follows: ½" plywood on ceiling costing $140/M; 3/8" plywood on sidewalls, $110/M; and corrugated sheet metal siding costing $13.70 per square. (100 sq. ft.)

The sheathing and siding cost of House No. 2 consisted only of baled straw, and was therefore minimal. The ceiling consisted only of poultry netting. The gothic roof (House No. 3) was somewhat lower than the frame house (No. 1) for sheathing costs, as all exterior sheathing was included as roof covering and included in the roof framing cost. The sheathing cost for the concrete block house (No. 4) was lower as only the ceiling cost and exterior siding on the gable ends was included.

TABLE 3—Costs of gothic roof frame house, house number 3

Material	Quantity	Unit cost	Subtotal cost	Total cost	Cost per square foot
Substructure					
Footing 8″ x 16″ continuous concrete	10 yds.	$16.00	$160.00		
Footing Rein. 2 continuous ½″ rods	576′	.10	57.60		
Foundation, 7 concrete blocks high	1,512	.22	332.00		
Total for substructure				$549.60	14.2¢
Framing					
Gable ends and plates, native lumber	547 bd. ft.	95./M	51.90		
Joists and supports, native lumber	4,270 bd. ft.	95./M	406.00		
Post, 6″ x 6″ x 8′, native lumber	672 bd. ft.	95./M	80.70		
Total for framing				538.60	13.9¢
Interior sheathing					
Ceiling, ⅝″ CD plywood	3,460 ft.²	180./M	623.00		
Walls, ½″ CD plywood	2,304 ft.²	140./M	323.00		
Interior sheathing, total				946.00	24.4¢
Exterior siding on ends					
6″ drop siding	690 bd. ft.	175./M	121.00	121.00	3.1¢
Vapor barrier plastic film, 4 mil	5,764 ft.²	.02	115.00	115.00	3.0¢
Insulation, shavings fill	8 loads	5./load	40.00	40.00	1.0¢
Windows, corrugated plastic					
2′ x 8′	160 ft.²	100./sq.	160.00		
2′ x 6′	10	2.50	25.00		
Total of windows				185.00	4.8¢
Doors, 2′-8″ x 6′-8″	2	27.30	54.60		
6′-0″ x 8′-0″	2	18.00	36.00		
2′-0″ x 6′-0″	2	15.00	30.00		
Total for doors				120.60	3.3¢
Nails—16d	1 keg	15./keg	15.00		
40d	20 lbs.	17./keg	2.55		
8d	1 keg	15./keg	15.00		
2S¼″ ring shank head	125 lbs.	30./keg	37.50		
Total cost for nails				70.05	1.8¢
Roof Construction					
Rafters, 5—1″ x 4″ boards laminated, commercial lumber	26	9.55	248.00		
Purlin roof deck, native lumber	2,445 bd. ft.	95./M	293.00		
Roofing, corrugated, 28 ga.	6,480 ft.²	13.70/sq.	897.00		
Ridge roll	108 ft.	.22	23.70		
Total for roof construction				1,461.70	37.5¢
Total Materials Cost				$4,147.55	$1.07

TABLE 4—Costs of concrete block poultry house, house number 4

Material	Quantity	Unit cost	Subtotal cost	Total cost	Cost per square foot
Substructure					
Footing 8" x 16" continuous concrete	10 yds.	$16.00	$16.00		
Footing Reinforced 2 continuous ½" rods	576 ft.	.10	57.60		
Foundation 7 concrete blocks high	1,512 blocks	.22	332.00		
Total for substructure				$549.00	14.2¢
Framing, gables, sills, native lumber	582 bd. ft.	95./M	55.20	55.20	1.4¢
Interior sheathing					
Ceiling, ⅝" CD plywood	3,880 ft.²	180./M	700.00	700.00	18.0¢
Exterior, 6" drop siding, commercial lumber	272 bd. ft.	175./M	47.60	47.60	1.3¢
Walls, 9 blocks high	1,944 blks.	.22	428.00	428.00	11.0¢
Vapor barrier, plastic film, 4 mil	3,880 ft.²	.02	77.60	77.60	2.0¢
Insulation, 8" shavings in ceiling	4 loads	5./load	20.00	20.00	.5¢
Windows, 2'-4'	26	2.00	52.00		
Wood louvers	2	14.00	28.00		
Total for windows				80.00	2.1¢
Doors, 2'-8" x 6'-8"	2	27.30	54.60		
6'-0" x 8'-0"	2	18.00	36.00		
Total for doors				90.60	2.3¢
Nails—16d	8 lbs.	15./keg	1.20		
6d	25 lbs.	15./keg	3.75		
Total for nails				4.95	.1¢
Roof construction					
Glue-Nail trusses	28 trusses	16.10	452.60		
Roof girts	1,580 bd. ft.	135/M	214.00		
Roofing	45½ sq.	13.70	622.00	1,288.60	33.2¢
Total Materials				$3,341.55	$0.86

Insulation cost differentials were due mainly to whether commercial or native materials were used. It may be noted that with 2" commercial blanket in the ceiling and the sidewalls and a complete vapor barrier sheet, as was used in House Nos. 1 and 5, the total cost of this component was only 10 cents per sq. ft. of floor area.

Miscellaneous items run up as high as 10 cents per sq. ft. of floor area. This includes such items as windows, doors and nails.

A particularly significant aspect of this cost analysis was the nearly equal costs of the roof framing plus covering. The clear-span wood truss roof framing calculated for House Nos. 1, 4 and 5 actually was somewhat less in cost, about 33 to 34 cents per sq. ft. of floor area, than the post-supported ceilings and roofs of House Nos. 2 and 3. In this comparison the arched, gothic-type roof of House No. 3 provided

an unobstructed second floor. To make this space usable for storage, only a floor need be added, whereas to utilize this area for poultry, wall insulation and sidewall sheathing must be added.

TABLE 5—Costs of insulated pole frame house, MSU Plan No. 727-Cl-87, house number 5

Material	Quantity	Unit cost	Subtotal cost	Total cost	Cost per square foot
Substructure					
Concrete pads, 8" thick x 20" diameter	5 yds.	$16.00	$80.00		
Treated sills, 2" x 6"	288 bd. ft.	130./M	37.40		
Total for substructure				$117.40	3.0¢
Framing					
Poles, 14', 6' diameter tops	24	3.81	91.50		
Walls, gables, door, window, native lumber	2,387 bd. ft.	95./M	226.50		
Total for framing				318.00	8.2¢
Interior sheathing, native lumber					
Ceiling, ½" plywood, 3,880 ft.²	3,880 bd. ft.	140/M	543.00		
Walls, ⅜" plywood, 2,304 ft.²	2,304 bd. ft.	110/M	254.00		
Total for internal sheathing				797.00	20.6¢
Exterior siding					
Siding, corrugated, 28 gage	2,500 ft.²	13.7/sq.	343.00	343.00	8.8¢
Vapor barrier, plastic film, 4 mil	6,184 ft.²	.02	119.00	119.00	3.1¢
Insulation					
Walls, 2" blanket	2,304 ft.²	47./M	108.40		
Ceiling, 2" blanket	3,880 ft.²		182.36		
Total for insulation				290.76	7.5¢
Windows					
Plex-O-Glas, 2' x 6'	18	2.50	45.00		
Louvers, 4' x 6'	2	14.00	28.00		
Total for windows				73.00	1.9¢
Doors, 2'-8" x 6'-8"	2	27.30	54.60		
8' x 8'	1	27.20	27.20		
Total for doors				81.80	2.1¢
Nails—40d	10 lbs.	17./keg	1.70		
20d	25 lbs.	17./keg	4.25		
16d	8 lbs.	15./keg	1.20		
8d	75 lbs.	15./keg	10.50		
2¼" ring shank head	50 lbs.	30./	15.00		
Total for nails				32.65	.8¢
Roof Construction					
Ring Bolt trusses	28 trusses	18.00	504.00		
Roof girts	1,580 bd. ft.	135/M	214.00		
Roofing, 28 ga.—Cord. Steel	45½ sq.	13.70/sq.	622.00		
Total for roof construction				$1,340.00	34.4¢
Total for Pole Frame Building				$3,843.61	$0.90

SUMMARY AND DISCUSSION

Four experimental poultry houses of different types of construction and one utility building, all totaling about 2000 sq. ft. of floor area, were constructed for slightly over $3.00 per sq. ft. at the Upper

TABLE 6—Cost of structural components of five poultry houses, dollars per square foot

	House number				
	No. 1	No. 2	No. 3	No. 4	No. 5
Substructure	.142	.037	.142	.142	.030
Framing	.042	.108	.139	.124	.082
Sheathing (in and out)	.406	.041	.275	.193	.294
Insulation and vap. bar.	.102	.054	.040	.025	.106
Misc. windows, doors, nails	.091	.051	.099	.045	.048
Roof frame and cover	.344	.372	.375	.332	.344
Total cost/sq. ft.	$1.13	$0.66	$1.07	$0.86	$0.90

Peninsula Experiment Station, M.S.U., Chatham, Michigan in 1957. The $30,000 expenditure for buildings resulted in a cost allocation as follows:

55 percent for materials and site preparation.
15 percent for utilities.
30 percent for labor.

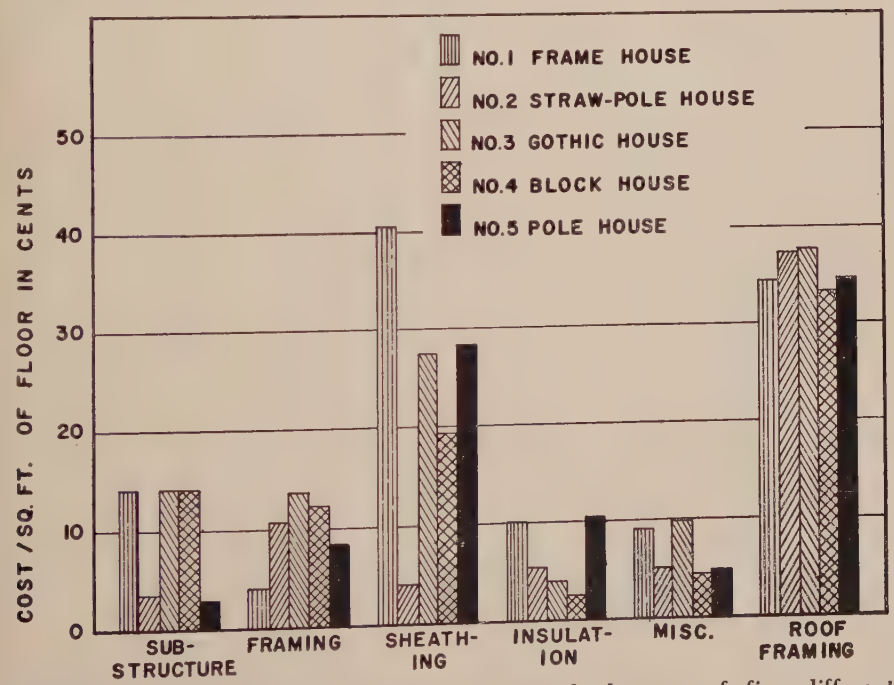

Fig. 12. Comparative costs of the structural elements of five different poultry houses.

It is noted that the labor cost was 43 percent of the materials and utilities cost or, figured another way, it was 55 percent of only the materials cost for the buildings.

This cost analysis pertains to the four types of poultry houses constructed at the Experiment Station in 1957 and the Michigan Tempered Air House, Plan No. 727-C1-87, as follows:

1. Insulated Frame.
2. Baled Straw-Pole Frame.
3. Gothic Roof Frame.
4. Concrete Block.
5. Insulated Pole Frame (Plan No. 727-C1-87).

For purposes of practicality, the cost analysis is based on buildings 36′ x 108′ in size, rather than the 36′ x 54′ actual size of the experimental buildings. Unit prices for all materials are based upon those paid for the actual construction of the four experimental buildings during the summer of 1957. A study of the materials list reveals that considerable native lumber was used for the framing of all four experimental poultry houses. Commercial dimension lumber was used for all clear-span roof trusses. Also, osmose treated used poles were used for the baled straw building (House No. 2).

Tables 1 through 5 do not include labor or ventilation and interior mechanical equipment required for a poultry enterprise. Labor costs vary with the locality and with the different types of building construction. No breakdown of labor cost was possible on this project except on the total project basis. Equipment costs would also vary with the degree of mechanization desired and the type of equipment used. All of the houses, particularly those with clear-span roof construction, are adaptable to most any arrangement of equipment.

The following points should be considered in comparing costs of the types of building construction and the separate costs of various building components.

1. The baled straw poultry house (House No. 2) is less permanent than the others and the inside environment is more directly dependent upon outside climatic conditions than the other completely closed, mechanically ventilated houses.
2. The concrete block house (House No. 4) is low in wall insulation as compared to the frame walls with fill or blanket insulation.

3. The laminated arch (Gothic House No. 3) has the volume and framing strength to accommodate a second floor for poultry or storage of litter and equipment. Flooring would be required for either purpose and additional sidewall insulation and interior wall sheathing would be required for poultry.
4. Clear-span roof construction (House Nos. 1, 4 and 5), without greater cost, provides for more flexibility of use and equipment arrangement than where interior posts are present (House Nos. 2 and 3).
5. Pole frame poultry houses without concrete foundations are somewhat more difficult to make rodent proof unless complete concrete floors are provided.
6. A frame type poultry house may be adequately insulated with commercial blanket insulation materials for approximately 10 percent of total materials cost.
7. Exterior and interior sheathing materials make up a major cost item of frame type poultry houses. (House No. 1 sheathing cost was 40 cents per sq. ft. of floor area). These materials should be selected for their durability and economic characteristics rather than for insulation.
8. Cost estimates for the frame structures (House Nos. 1, 2, 3 and 5) might be 25 percent higher if the higher costs for all commercial dimension lumber and pressure treated poles and sill planks are included.

POULTRY SCIENCE RESEARCH AT THE UPPER PENINSULA EXPERIMENT STATION

Chatham, Michigan

II. Time of Egg Laying in the Domestic Fowl[1]

By L. R. CHAMPION and H. C. ZINDEL

DEPARTMENT OF POULTRY SCIENCE

IN A DISCUSSION ON the management of chickens, Card (1952) raised several questions on the nature of the activities of hens. One of the questions was, "Does a hen always, or usually, lay in the same nest?" While this particular question does not pertain to the information reported herein, it bears a close association to our question which similarly involves the activities of chickens—"What proportion of the eggs laid by modern-day chickens are laid in the forenoon?"

The importance of this question at first glance, and with little reflection, may appear to be superficial. However, in view of the extremely rapid expansion of the poultry industry and the concurrent magnification of poultry house management problems, coupled with highly competitive marketing conditions, increased emphasis must, of necessity, be placed upon attention to details, if a successful poultry enterprise is to be enjoyed. The design of the laying house; the type, quantity and location of equipment; the frequency of egg-gathering; the production of clean-shelled eggs; the reduction of the number of floor eggs; the prevention of the development of the egg-eating habit by the birds; and the development of measures which can be adopted to prevent or reduce deterioration of interior egg quality, among others, are all fundamental problems and important considerations which involve behavior or activity patterns.

Coupled with each of the foregoing items is that inseparable and estimable component—labor efficiency. As Card (1952) so aptly stated,

[1]This work is in cooperation with the North Central Regional Poultry Breeding Project, NC-47.

ARTICLE 43-21

"The answers to such questions may not appear to be of much significance, but in the aggregate they measure that indefinable something which goes with successful poultry management . . ." Thus, since no recent work seems to have been carried out on the time of egg laying in the fowl, it was considered desirable to obtain data on this subject.

A review of the literature pertaining to the nesting habits of the chicken has failed to reveal any information on this subject since the early investigations of Goodale (1915), Patterson (1916), and Turpin (1918). Goodale (1915) discussed the "rhythmic" nature of egg production and stated that the time a specific female laid an egg was largely dependent upon her particular rhythm, and also that each female had a rhythm which was fairly uniform. If a female lays at the rate of one egg every other day, she usually lays at approximately the same time every second day. If a female lays two days out of three, the first egg is laid in the a.m. and the second in the p.m. He further observed that chickens with a longer uninterrupted, or continuous, period of production, laid the larger proportion of their eggs prior to noon. Apparently, Goodale's (1915) "rhythm of egg production" is that which today is referred to as "clutch" length or "cycle" of egg production. Patterson (1916) used the term "cycle" to mean the number of eggs a hen lays without missing a day and "rhythm" to signify the repeatability of the rhythm of the cycle. From his study of hens entered in the egg laying contests at Missouri, he found "that where hens lay cycles of more than four eggs, by far the greater percent were laid in the forenoon". No data as to numbers of eggs laid prior to noon, or actual percentages were given. It is noteworthy that the total egg production for the highest producer was 187 eggs and the lowest producer laid 96 eggs.

Turpin (1918), using W. Leghorns, recorded for a two-month period in the spring (March 20-May 20), the time that Leghorn layers were removed from trapnests. He found that the total percentage of hens laying up to the hour indicated were as follows: 9 a.m.—17.7 percent, 11 a.m.—28.5 percent, 1 p.m.—27.3 percent, 3 p.m.—19.5 percent, and 5 p.m.—7.0 percent. Cumulatively, 73.5 percent of the hens had laid up to 1 p.m.

Facilities at the Upper Peninsula Experiment Station.—For a complete description of the poultry facilities at Chatham see Esmay, Champion and Zindel (1960).

1957-1958 Test Period.—In September, 1957, 1,948 pedigreed S. C. White Leghorn pullets hatched and reared at Michigan State University were trucked to Chatham. Two university trucks, loaded with 114 crates and 16 or 17 pullets in each crate, left East Lansing at 7 p.m. on a Sunday. They arrived at Chatham after 13 hours of driving. Only one pullet was lost enroute and a total of 14 eggs were laid enroute. The pullets were hatched from eggs produced by selected parental stocks which represented two pure strains in both pure strain and strain-cross matings. Approximately equal numbers of pullets, representing each of the four kinds of breeding, were placed in each pen. At a density of 487 females per pen, each female had 3.3 square feet of floor space. Eggs were gathered at 8:00 and 11:00 a.m., and at 1:00 and 4:00 p.m. during the test period.

1958-1959 Test Period.—The same system of breeding and management employed to produce the 1957-58 pullets was followed. The period of the test was advanced, however. Further, since the performance of the females during the first winter of operation had demonstrated that the layers housed at 3.3 square feet of floor space per bird did not produce sufficient body heat to keep the internal pen temperatures as warm as planned, an increase in the number of females housed per pen was made.

In June, 3,524 pullets were trucked to Chatham from East Lansing. The oldest pullets were placed in Pens 2, 3 and 4 at the following densities: Pen 2—640, Pen 3—640, Pen 4—540. Thus, each bird had 2.5 square feet of floor space. The 1,604 females which were placed into Pen 1 had 1 square foot of floor space per pullet. Data were collected beginning July 1 in Pens 2, 3 and 4 and August 1 in Pen 1. Eggs were gathered at 8:00 and 11:00 a.m. and at 1:00 and 4:00 p.m. during this test period.

1959-1960 Test Period.—In June, 1959, the distribution of 3,676 pullets into the pens at Chatham was as follows: Pen 1—1238, Pen 2—802, Pen 3—802, Pen 4—682, Pen 5—38, Pen 6—38 and Pen 7—76. In Pen 1, each female had 1.25 square feet of floor space, whereas in all other pens each female had 2.0 square feet of floor space. The M.S.U.-bred portion of the population housed were another generation of individuals of the two pure strains and reciprocal strain-crosses. However, part of this population was brooded and reared at a substation (W. K. Kellogg Farm, Hickory Corners, Michigan) both indoors and on range. All pure strain and strain-cross individuals brooded

at M.S.U. were reared on range. Further, a new population of pullets of distinctly different breeding were brooded at the home station and reared either in confinement or on range. Approximately equal numbers of females, representing the various populations and rearing treatments, were placed in each pen at Chatham. During this test period, the eggs were gathered between the following hours: 7-8 a.m., 10-11 a.m., 12-1 p.m., and 3-4 p.m. Data were collected from July 1 through April 30, 1960.

Shavings were used as the litter material in all pens and a deep litter management system was followed. The birds were fed an all-mash laying ration *ad libitum*. Supplemental pellets, in quantities based on the number of birds in each pen, were fed in the late afternoon between four and five p.m. During the 1957-58 year of operation, a 14-hour light day was provided. From September 1 to June 30, the lights were turned on at 4 a.m. and turned off at 6 p.m., and from July 1 to August 31 the lights were turned on at 5 a.m. and turned off at 7 p.m.

Prior to the second year of operation, a photoelectric cell was installed in each pen to guarantee a minimum lighting in each pen during the day. Each photoelectric cell was regulated to turn the artificial lights on when the interior pen lighting during the day light hours was less than 1 foot-candle[2], (Fairbanks and Heuser, 1939; Wilson, 1958), and to turn the lights off when the lighting was more than 3 foot-candles. The electric eyes are located over the feeder and water troughs but not facing the windows. A stand-by generator unit is located in the service building and thus the complications which would result from power failure are minimized.

RESULTS

1957-1958.—The proportion of eggs laid in the forenoon, by months, for the females in each pen are plotted and shown in Fig. 1. It is apparent from these data that the proportion of eggs laid in the forenoon by females just coming into production is considerably less than the proportion of eggs laid prior to noon, after the females have been laying eggs for several months. From these data, it is suggested that this pattern of activity or time of egg laying becomes "established" with greater uniformity due to a more uniform and "timed-sequence" in the regulation of the physiological, i.e., endocrine, system. Further,

[2]A foot-candle is the amount of illumination given by a standard candle at a distance of 1 foot.

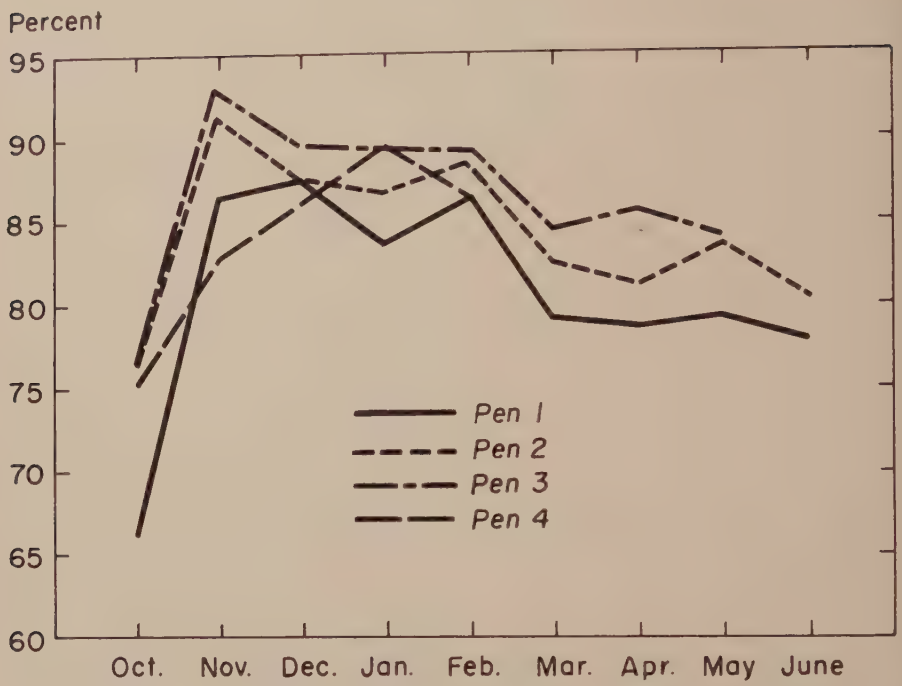

Fig. 1. Proportion of eggs laid prior to noon, 1957-58, Chatham data.

these data support the view that the proportion of eggs laid in the forenoon will be greatest during peak egg production periods and that as intensity or rate of lay decreases, the proportion of eggs laid in the morning will decrease.

The pooled monthly data, by pens, is presented in Table 1. It may be seen that there is a difference of only 6.21 percent between the individuals in the "high" and the "low" pens (1957-58) in the percentage of eggs laid prior to noon. The pooled data shows that of the 203,374 eggs laid by the individuals in all pens, 84.06 percent were laid in the forenoon.

1958-1959.—Figure 2 shows the proportion of eggs laid in the forenoon, by months, by females in Pens 1 to 4, inclusive. The data on the total number of eggs laid by the females during the test period of approximately nine months, and the percentage of those eggs which were laid in the forenoon, are presented in Table 1. The difference between the proportion of eggs laid prior to noon by the individuals in the "high" pen and the "low" pen was 3.44 percent. The pooled data showed that 88.01 percent of the 298,724 eggs produced, were

TABLE 1—Proportion of eggs laid prior to noon, Chatham, data, 1957-58, 1958-59

Pen	1957-58		1958-59		All years	
	No. eggs laid	Percent a.m.	No. eggs laid	Percent a.m.	No. eggs laid	Percent a.m.
Pen 1	65,618	80.77	142,867	88.13	208,485	85.81
Pen 2	54,891	84.20	58,792	88.66	113,683	86.50
Pen 3	61,638	86.98	62,165	87.63	123,803	87.31
Pen 4	21,227	85.38	34,900	85.22	56,127	85.28
Total number eggs laid	203,374	.....	298,724	.....	502,098	.....
Weighted average percent, a.m.	.....	84.06	.....	88.01	.....	86.28

laid in the a.m. For both years, 86.28 percent of the ½ million eggs produced were laid in the forenoon.

1959-1960.—The egg gathering procedure in all pens was changed for this test period. Eggs were gathered between the hours of 7-8 a.m., 10-11 a.m., 12 a.m.-1 p.m., and 3-4 p.m. The proportion of eggs laid by the females, in all pens, was plotted by months and is shown in

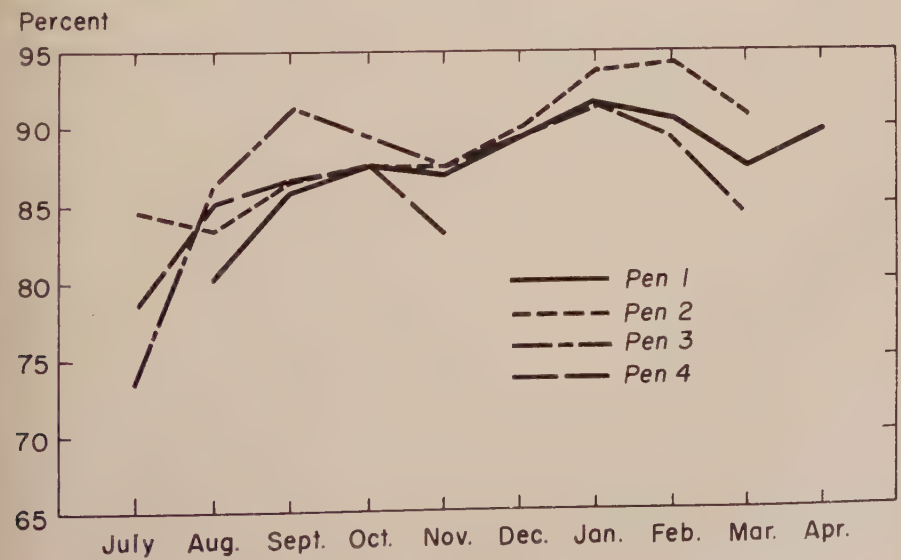

Fig. 2. Proportion of eggs laid prior to noon, 1958-59, Chatham data.

Fig. 3. As presented in Table 2, 38.86 percent (214,403 eggs) of the total eggs laid by all of the females during this test (551,755 eggs), were laid prior to 8 a.m., 31.58 percent (174,251 eggs) were laid between the hours of 8 a.m. and 11 a.m., 18.54 percent (102,300 eggs) were laid between the hours of 11 a.m. and 1 p.m., and 11.02 percent (60,801 eggs) were laid from 1 p.m. to 4 p.m. The pooled data showed that 70.44 percent of the eggs were laid prior to 11 a.m. and that 88.98 percent of the total eggs laid were laid prior to 1 p.m.

DISCUSSION

It has frequently been stated that the interior quality or "I.Q." of an egg will never be any better than the interior quality of that particular egg at the time it is laid. After oviposition, or the act of egg-laying, what happens to the interior quality of the egg depends, in large part, upon the treatment and care that the egg receives by man.

The chicken egg has become recognized as being among the most delicate and perishable food products. High temperatures probably

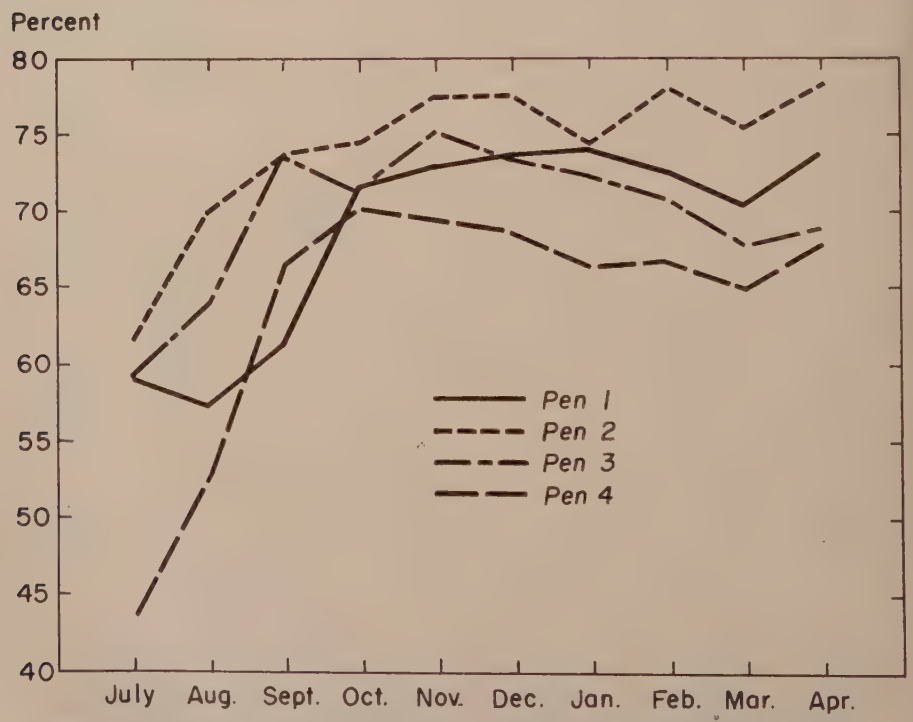

Fig. 3. Proportion of eggs laid prior to 11 a.m., 1959-60, Chatham data.

TABLE 2—Time of egg laying in the chicken—1959-60

Time	7 a.m.-8 a.m.		10 a.m.-11 a.m.		12 a.m.-1 p.m.		3 p.m.-4 p.m.		Total number eggs laid
	No. eggs laid	Per-cent	No. eggs laid	Per-cent	No. eggs laid	Per-cent	No. eggs laid	Per-cent	
Pen 1.....	71,177	37.85	58,391	31.05	39,254	20.88	19,218	10.22	188,040
Pen 2.....	51,163	41.19	41,645	33.53	20,756	16.71	10,649	8.57	124,213
Pen 3.....	52,701	39.67	42,263	31.81	22,371	16.84	15,512	11.68	132,847
Pen 4.....	39,362	36.90	31,952	29.96	19,919	18.68	15,422	14.46	106,655
Total number eggs laid.....	214,403	...	174,251	...	102,300	...	60,801	...	551,755
Weighted average, percent ..	.....	38.86	.....	31.58	.....	18.54	.....	11.02	.....

cause more deterioration in interior egg quality than any other factor. At warm temperatures, a liquefaction or breakdown of the thick albumen occurs, the vitelline membrane (yolk membrane) is weakened and the yolk becomes flattened and an evaporation of the egg contents with a resulting enlargement of the air cell takes place. These undesirable changes occur with amazing rapidity and hence, one of the first factors emphasized in preventing deterioration of interior egg quality is prompt and proper cooling. With the increased emphasis being placed upon the production of high quality eggs, it is understandable that the commercial egg-producer should pay strict attention to all those facets of egg production and egg-handling which will aid in keeping the loss of original interior egg quality to a minimum.

The nesting and egg-laying habits or activities of the hen are, at least in part, related to quality egg production. Jackson (1912) reported that the ". . . laying hen regularly remains on the nest for a period ranging from one-half to two hours when laying . . ." Turpin (1918) reported that the average time a hen spent on the nest to lay an egg was 1 hour and 45 minutes for R. I. Reds, 1 hour and 35 minutes for Leghorns, and 2 hours and 16 minutes for White Plymouth Rocks. The high figure for the W. P. Rocks was due to an extreme length of time spent on the nest by three females. He also found that open front nests were more attractive to the hens when they contained

at least one egg. It, therefore, becomes immediately apparent that since the nesting habit of the female is to spend approximately two hours on the nest to lay an egg, and also that she is more apt to select a nest which contains a previously laid egg, frequent egg collection is one means of reducing the exposure of eggs to high temperatures. (The average body temperature of a normal hen is within the range of 106.0-107.0° Fahrenheit—Hewang, 1938; Robinson and Lee, 1946).

The generally accepted recommendation for frequency of egg-gathering is that from 2 to 3 egg collections per day are sufficient. Considering the foregoing information and the data presented herein on the proportion of eggs laid in the forenoon or to 1 p.m., it would seem that a more appropriate and practical recommendation of egg-gathering is that a minimum of four egg collections should be made up to 1 p.m., and one additional egg-collection should be made in the late afternoon. It is entirely possible that a more frequent egg collection schedule in the morning not only will minimize egg quality losses but will also materially reduce the incidence of floor eggs and dirty eggs. Further, afternoon labor schedules can be formulated which will involve duties and chores other than egg-collection.

The tabular two-year data (1957-58, 1958-59) showed that the chickens used in this investigation laid 86.28 percent of their eggs in the forenoon. The 1959-60 data, compiled for egg-gathering times of 7-8 a.m., 10-11 a.m., 12 a.m.-1 p.m., and 3-4 p.m. showed that 88.98 percent of the eggs were laid prior to 1 p.m. The percentage of eggs gathered to 1 p.m. was considerably higher (15.38 percent) than the 73.5 percent reported to have been laid up to 1 p.m. by S. C. White Leghorns trapnested for a two-month period, March 20-May 20, by Turpin (1918). Thus, it is apparent that present-day chickens, with a significantly greater rate of lay than stocks bred several decades ago, will lay a greater proportion of their eggs in the forenoon than that reported by Turpin (1918). Further, these data indicated that the nesting habits or egg-laying activities of the female are not influenced to any appreciable degree by the type or style of the laying nest (roll-away or circular egg parlor).

SUMMARY

Three years' data were collected on the time of egg laying in the domestic fowl. During the 1957-1958 and 1958-1959 test period, eggs were gathered at 8:00 and 11:00 a.m., and at 1:00 and 4:00 p.m. Egg

collections were made between the hours of 7-8 a.m., 10-11 a.m., 12-1 p.m., and 3-4 p.m. during the 1959-1960 test period.

The proportion of eggs laid prior to noon during 1957-1958 and 1958-1959 were 84.06 and 88.01 percent, respectively. The pooled data showed that 86.28 percent, of the 502,098 eggs laid, were laid in the forenoon. The 1959-60 data showed that 38.86 percent of the total eggs laid (551,755) were laid prior to 8 a.m., 31.58 percent of the eggs were laid between the hours of 8 a.m. and 11 a.m., 18.54 percent of the eggs were laid between the hours of 11 a.m. and 1 p.m., and 11.02 percent of the eggs were laid between the hours of 1 p.m. and 4 p.m.

The pooled data showed that 70.44 percent of the eggs were laid prior to 11 a.m., and that 88.98 percent of the eggs were laid prior to 1 p.m. The proportions of eggs laid in the forenoon, as presented herein, are substantially greater than those reported in the early literature.

It is apparent from these data that the generally accepted recommendation for frequency of egg-gathering (2-3 times per day) must be revised. Therefore, it is recommended that a minimum of four egg collections be made up to 1 p.m., and that one additional egg collection should be made in the late afternoon. Reasons are presented for the postulation that a more frequent egg collection schedule in the a.m. may contribute greatly to keeping losses of interior egg quality to a minimum. Further, it is suggested that the adoption of the practice, on commercial egg farms, of an increased frequency of egg gathering should materially help to reduce the incidence of floor eggs and dirty eggs. These data also indicated that the type or style of the laying nest did not play an important role in determining the nesting habits or egg-laying activities of the females.

LITERATURE CITED

Card, L. E. (1952). *Poultry Production.* Lee and Febiger, Philadelphia, 8th ed. 416 pp.

Esmay, M. L., L. R. Champion and H. C. Zindel (1960). Poultry science research at the upper peninsula experiment station, Chatham, Michigan. I. The engineering and cost aspects of the basic structure of five types of poultry houses. Mich. Agr. Expt. Sta. Quart. Bul. 43: pp. 170-187.

Fairbanks, F. L., and F. G. Heuser (1939). Artificial illumination of poultry laying houses for winter egg production. Cornell Agr. Expt. Sta. Bul. 411: 1-25.

Goodale, H. D. (1915). On the rhythm of egg production. Jour. Amer. Assoc. Inst. and Invest. in Poultry Husb. 1:18.

Heywang, B. W. (1938). Effect of some factors on body temperature of hens. Poultry Sci., 17: 317-323.

Jackson, H. W. (1912). Experiments in incubation. Pa. Agr. Expt. Sta. Bul. No. 20: 209-219.

Patterson, C. T. (1916). Cycles and rhythm of egg production. Jour. Amer. Assoc. Inst. and Invest. in Poultry Husb. 3:16, 20.

Robinson, K. W., and D. H. K. Lee (1946). Animal behavior and heat regulation in hot atmospheres. Univ. Queensland Papers 1:1.

Turpin, G. M. (1918). The nesting habits of the hen. Iowa Agr. Expt. Sta. Bul. 178: 211-232.

Wilson, Wilbor O. (1958). Recommendations for use of lights for poultry as of June, 1958. Univ. of Calif., Davis. Mimeo Pub.

JOURNAL ARTICLE ABSTRACTS

Influence of the Seedball on Speed of Germination of Sugar-Beet Seeds

SNYDER, F. W.

Jour. Amer. Sco. Sugar Beet Technol. 10: 513-520. 1959. (Journal Article 2066 from the Michigan Agricultural Experiment Station)

The effect of physical and chemical factors of the seedball on speed of germination was studied. Seeds in seedballs, notched to expose a portion of each true seed, germinated more rapidly than those in whole seedballs of the same variety. The tightness of the seedcaps over the true seeds differed among varieties. Seeds in the whole seedballs from two plants of variety US 401 germinated more rapidly than isolated true seeds obtained from the same seedlots, indicating a stimulating effect of the seedball. The growth of the seedlings also was stimulated by the seedballs. The seeds were germinated in contact with a mineral nutrient solution of 10.1 atmospheres osmotic pressure.

The Effectiveness of Various Manganese Materials in Supplying Manganese to Crops

SHEPHERD, L., K. LAWTON AND J. F. DAVIS

Soil Sci. Soc. Am. Proc., 24: 218-221. 1960. (Journal Article 2163 from the Michigan Agricultural Experiment Station)

Field test on Houghton muck and greenhouse studies on alkaline organic and mineral soil were conducted to determine the comparative effectiveness of several manganese carriers as measured by yield response and manganese content of crops. Carriers used were manganese sulfate, NuM, Mangasoil, NuManese and Fn 239B frit in the field studies. In addition to the above five carriers, FN 502 frit and disodium manganese EDTA were used in the greenhouse.

In the field studies the methods of application in order of effectiveness in increasing the yield of onions were banding, broad-casting and spraying. The 1957 data indicates no difference in the effectiveness of the various carriers to increase the yield of onions when they are mixed with the basic fertilizer and banded 2 inches below the seed at planting time. Greenhouse results indicated a high residual value on Houghton muck for EDTA followed by FN 239B frit, Nu Manese and manganese sulfate.

Bromine Retention in Some Soils and Uptake of Bromine by Plants After Soil Fumigation

STELMACH, ZENOBIUS

Soil Sci. 88: 61-96. 1959. (Journal Article 2200 from the Michigan Agricultural Experiment Station)

Cabbage, string beans, and table beets were grown in several soils to which bromine had been applied. Beans and cabbage were highest in bromine when

at peak growth. Beets grown in the greenhouse containing as much as 1062 ppm bromine grew faster than those not treated but a much smaller content of bromine in field grown beets caused injury to the growth. Drought was more injurious where bromine was applied. Bromine caused increases in yield in 1954, with one exception, but was non-effective in 1953. Bromine retention by soils was in the order of exchange capacity, highest in muck soil, lowest in sand. The highest content of bromine in untreated beans was in stems while the least was in the leaves. Roots fell in between. In the bromine treated soil the greatest content of bromine was in bean roots, with least in the stems.

Variations in Respiratory Responses in Fusarium-Infected Tomato Plants

SCHEFFER, R. P.

Phytopathology 50: 192-195. 1960. (Journal Article 2311 from the Michigan Agricultural Experiment Station)

Infection of tomato plants by *Fusarium oxysporum* f. *lycopersici* stimulated gas exchange by leaf tissue under some conditions, but not others. Leaves of infected plants grown in a low-N regime had a much higher 0_2 uptake than leaves of non-infected low-N controls. Plants grown in a high-N regime did not respond to infection by increased 0_2 uptake by leaves. The degree of stimulation of 0_2 uptake varied with the season, being maximum under conditions of high light intensity and long days, and minimum under low light short day conditions. The same trends were found for stem tissue containing the causal fungus in minute amounts. Since symptom development is not necessarily accompanied by increased respiration in leaves, results suggest that such disturbances may be secondary factors in pathogenesis. The evidence indicates also that toxins carried in the transpiration stream are not significant factors in disease development.

Some Effects of Gibberellin on Stem Elongation and Flowering in Sugar Beets

SNYDER, F. W. and S. H. WITTWER

Jour. of the Am. Soc. of Sugar Beet Tech. 10: 554-561. 1959. (Journal Article 2358 from the Michigan Agricultural Experiment Station)

Flowering in sugar beets may be accelerated, and even induced, with gibberellin, if treatments (repeat spray applications of solutions of 1,000 p.p.m. to the growing tips) are accompanied by exposure of the plants to a long (18-hour) photoperiod. At an 18-hour photoperiod and a night temperature of 55°F, gibberellin promoted earlier flowering than in the non-treated plants in both annual (SL 9460) and biennial (US 400) sugar beets. No normal flowering occurred at a 9-hour photoperiod. Appreciable flowering was induced with gibberellin (40 percent of treated plants) in US 400, a biennial variety of intermediate bolting tendency, grown at a non-inductive temperature (65°F.) if the plants were simultaneously exposed to a long (18-hour) photoperiod. The results of these findings should prove useful for promoting earlier flowering and seed production as a means of accelerating variety improvement programs. Further testing under field conditions is needed before the value of gibberellin can be assessed in commercial sugar beet seed production.

Chemical, Anatomical and Histochemical Studies on the Navy Bean Seed

Powrie, W. D. and I. J. Pflug

Agron. Jour. 52: 163-167. 1960. (Journal Article 2391 from the Michigan Agricultural Experiment Station)

This study was undertaken in order to fulfill the need for additional chemical and structural information on the navy bean seed. Data on the gross structure and chemical composition of the bean have been presented. The seed coat, cotyledons and embryonic axis constituted 7.7%, 90.5% and 1.8% of the dry matter of the bean, respectively. Although a relatively small amount of protein was found in the seed coats, (4.8%), the cotyledons and embryonic axis were rich sources of protein with 27.5% and 45.6%, respectively. The starch content of the cotyledons was determined to be 39.3%. Determinations of ash and fat in various tissues also have been included.

Since many quality characteristics of the bean are dependent on the structure of the cotyledon, detailed anatomical and histochemical studies on this tissue were carried out. The cotyledon, for the most part, consists of parenchyma cells which were covered by epidermal and hypodermal layers of cells. Dimensions of the specific cells and cell walls, discussion of anatomical structure and histochemical observations have been presented. Within each parenchyma cell, starch granules were imbedded in a protein matrix. Starch granule dimensions and physical characteristics have been reported.

The Sodium-Potassium Nutrition of Sugar Beets Produced on Organic Soil

Shepherd, L. N.; J. C. Shickluna and J. F. Davis

Jour. Am. Sugar Beet Tech. 10: 603-608. 1959. (Jour. Article Number 2401 from the Michigan Agricultural Experiment Station)

This study was initiated at the Muck Experimental Farm to determine the yield response of sugar beets to salt at various soil test levels to potassium as measured by soil test, and to determine yield response of sugar beets to salt when additional potassium was applied as fertilizer across soils varying in levels of potassium.

The data obtained show that the yield response of sugar beets to salt applications decreased with increased rates of potash applied. Salt applied at 500 pounds per acre across plots that received 600 pounds of potash per acre tended to depress the yield of sugar beets.

The data indicate an inverse relationship between the potassium and sodium content of the sugar beet tissue in that high levels of potassium tended to reduce the sodium content and vice versa.

The large loss of potassium as indicated by soil test to determine fertilizer recommendations for sugar beets.

The Inheritance of Shank Color in a Jungle Fowl–Silver Cornish Cross

Henderson, Earl W.

Poultry Sci. 39: 53-56. 1960. (Journal Article 2440 from the Michigan Agricultural Experiment Station)

From shank colors of progenies of Silver Cornish and a strain of Wild Red Jungle Fowl mated *inter se* and reciprocally crossed, it was determined that the

genotype of the blue shank color of a population of Wild Red Jungle Fowl is similar to that of domestic fowl. The blue shank color of the Red Jungle Fowl appears to be sex-linked (id id) and autosomal (WW) for males and (id__ WW) for females. There was some slight evidence of incomplete dominance of both genes. The genotype of the Silver Cornish appeared to be 100% (Il Id ww) in males and (Id__ ww) in females.

The Value of Corn Fermentation Solubles in Poultry Nutrition

TSANG, SIMON T. L. AND PHILIP J. SCHAIBLE

Poultry Science. XXXIX. No. 2: 251-257. 1960. (Journal Article 2443 from the Michigan Agricultural Experiment Station)

Three experiments were carried out to evaluate the nutritive value of a commercial-type product of corn fermentation solubles in practical broiler diets and to compare it with recognized sources of unidentified growth factors.

It was found that this product supplied unidentified growth factor(s) required by chicks for rapid growth and provided utilizable protein and energy. Under the specific experimental conditions used, it replaced equivalent amounts of fish meal in a corn-and-soybean-oil-meal type of ration; it stimulated growth best in diets containing over a thousand calories of productive energy per pound.

Dried distillers solubles also replaced fish meal under the experimental conditions.

The Drying Rate of Alfalfa Hay

PEDERSEN, THOMAS T. AND WESLEY F. BUCHELE

Agr. Engr. 41: 86-89, 107-108. 1960. (Journal Article 2447 from the Michigan Agricultural Experiment Station)

Because hay is the most important forage crop in the United States, it is important to develop a method of curing the hay to avoid high losses.

In order to increase the drying rates of the stems, different treatments were applied to alfalfa plants. This experiment showed that the fastest evaporation was obtained when the stems were hard crushed, or when the stems were penetrated several places per inch of length. Lower rates were recorded when the stems were twisted, smashed or cut in pieces of 2 inches in length.

When the hay was crushed, the drying rate of the leaves as well as that of the stems was increased. This increase, however, was considerably higher for the stems than for the leaves. If "hard-crushing" was applied, the stems dried faster than the leaves. It is thus evident that a complete break up of the cuticle causes the stem to dry faster than the leaves.

Nearly all the stomata were closed after 3 hours of drying. After this period, the drying rate decreased considerably and stayed nearly constant until equilibrium with the surrounding air was obtained.

The younger the alfalfa plant was cut, the higher the moisture content. The highest moisture content in the alfalfa plant was found in the growing parts of the plant.

Hay-in-a-Day Harvesting

PEDERSEN, THOMAS T. AND WESLEY F. BUCHELE

Agr. Engr. 41: 172-175. 1960. (Journal Article 2448 from the Michigan Agricultural Experiment Station)

Hay is the most important forage crop in the United States. Because field curing subjects hay to weather damage and as a result causes considerable loss of nutrients, it is important to find the best possible method of curing the hay.

By inserting a vapor barrier between the soil and the drying hay, the effect of evaporation from a wet soil was eliminated, and the time necessary to dry the hay to storable conditions was reduced.

When black polyethlene was used as a vapor barrier, it also absorbed radiation energy. The surface temperature was raised 40.3° F. above that of the surrounding air.

The results of this study indicated that hay moved before 10:00 A.M., crushed (clearance between rollers less than 0.015 inches) and placed on black polyethlene sheets, will dry to a storable moisture content of 20 percent before 4:00 P.M., and may be harvested the same day as cut.

Characterization of Several n-Alkyl Esters of Gibberellin A_3 and Their Comparative Biological Activity

SELL, HAROLD M., SANDRA RAFOS, MARTIN J. BUKOVAC AND SYLVAN H. WITTWER

Jour. of Organic Chemistry. 24: 1822. 1959. (Jour. Article 2462 from the Michigan Agricultural Experiment Station)

Ten n-alkyl esters of gibberellin A_3 were synthesized and tested for biological activity. Methyl, ethyl, n-propyl, n-amyl, n-hexyl, and n-heptyl gibberellates significantly increased the percent of lettuce seed that germinated with the methyl, ethyl, n-propyl, n-butyl, and n-amyl gibberellates equal to or approaching the activity of gibberellin A_3. Germination was not significantly enhanced by the n-octyl, n-nonyl, or n-decyl esters of the carboxyl grouping of gibberellin A_3. The promotive responses obtained from methyl, ethyl, n-propyl, n-butyl, n-amyl, n-hexyl and n-heptyl gibberellates in lettuce seed germination in the dark may have resulted from hydrolysis of the esters to the acid (gibberellin A_3) in the agueous germinating medium or hydrolysis within the seed or seedling after imbition.

The Application of Ultrasonic Reflection Techniques in Evaluating Fatness and Leanness in Pigs

PRICE, J. F.; A. M. PEARSON; H. B. PFOST AND R. J. DEANS

Jour. An. Sci. 19: 381-387. 1960. (Journal Article 2473 from the Michigan Agricultural Experiment Station)

An ultrasonic probing technique for measuring fat thickness on live hogs and pork carcasses proved to be as valuable as backfat thickness or live probe in predicting the cut-out value on 158 hogs. Correlation coefficients between fat thickness and percentage lean cuts were almost identical whether fat was measured by

ultrasonic probe, or ruler probe, or carcass measurement. Very high relationships were found between fat thickness measured on the live hogs with a ruler and that measured ultrasonically with r values of .81 and .91 in Group I (70 hogs), and Group II (84 hogs), respectively. Ultrasonic estimates of fatness offered little advantage over commonly used methods.

Ultrasonic estimates of the depth of the loin eye muscle were significantly related to actual depth measurements only in Group II. (r = .30 and .43, live and carcass estimates, respectively). These relationships were not sufficiently high to be directly useful for prediction.

The Enzymatic Expression of Heterozygosity in Families of Galactosemics

DONNELL, GEORGE N., WILLIAM R. BERGREN, ROGER K. BRETTHAUER AND R. G. HANSEN

Pediatrics 25: 572-581. 1960. (Journal Article 2475 from the Michigan Agricultural Experiment Station)

Galactose-1-phosphate uridyl transferase (transferase) has previously been found to be absent or deficient in galactosemics. Existing procedures for the measurement of this enzyme in erythrocytes have been modified so as to obtain quantitative levels. This procedure, when applied to 14 galactosemics, their families, and normal controls (total of 278 individuals) resulted in 3 distinct groups of transferase levels. Expressed as um UDPG utilized ml. red cell hr., these are: 1) 0-0.6; 2) 1.1-3.9; 3) 3.8-8.3. Group 1 includes only galactosemics. Group 2 includes both parents, at least one grandparent, and some relatives. Group 3 includes normal controls and other relatives. The intermediate level of transferase found in each parent and at least one grandparent confirms previous conclusions that the disease is genetic and transmitted as an autosomal recessive character.

(2-Chlorethyl) trimethylammonium Chloride and Related Compounds as Plant Growth Substances II. Effect on Growth of Wheat

TOLBERT, N. E.

Plant Physiology 35: 380-385. 1960. (Journal Article 2478 from the Michigan Agricultural Experiment Station)

Compounds of the structure $(CH_3)_3N\text{-}CH_2\text{-}CH_2X$ are active as plant growth substances when X is a Cl, Br or $= CH_2$ group. The trimethylamine group is necessary for activity. The length of the ethyl chain is optimum for maximum activity. Solutions of (2-chloroethyl) trimethylammonium chloride, (2-bromoethyl-trimethylammonium bromide) and (2, 3-n-propylene)-trimethylammonium bromide were active at 10^{-6} M when poured on soil. Treated wheat plants grew with shorter stems than control plants. In this report, these chemicals were tested as growth substances on wheat and other grains. The chemicals were effective when applied to the soil, sprayed on the leaves, or added by soaking of seeds before planting. The most characteristic growth alterations were shorter and thicker stems, broader and greener leaves, earlier and stronger tillering and more uniform growth. The growth changes are similar to those produced by high light intensity and the opposite from those caused by gibberellin. Gibberellin reverses the action of these compounds, and they reverse the effect of gibbrellin.

Interrelationships Between Calcium, Zinc, Iron and Copper in Swine Feeding

HOEFER, J. A.; E. R. MILLER; D. E. ULLREY; R. W. LUECKE AND H. D. RITCHIE

Jour. of An. Sci. 19: 249-259. 1960. (Journal Article 2485 from the Michigan Agricultural Experiment Station)

Three experiments involving a total of 158 weanling pigs were conducted to study the effect of adding zinc (50 or 75 ppm), iron (100 ppm) and copper (125 ppm) to rations varying in calcium level (0.155, 1.05 and 1.31%). Combinations of trace minerals were used in two of the experiments. Parakeratosis occurred at all three calcium levels and was completely prevented by the addition of zinc. Iron was ineffective in controlling parakeratosis, whereas copper, although less effective than zinc, significantly reduced the incidence and severity of the skin lesions. Copper also had a significant effect on growth, particularly at the higher calcium levels. Hemoglobin and hematocrit values were increased by all trace mineral supplementation. Serum alkaline phosphatase levels were influenced in a highly significant manner by the presence of zinc in the ration. Blood serum proteins, particularly the gamma globulin and albumin fractions were affected by the trace minerals added.

The Control of Estrus and Ovulation in Gilts by Orally Effective Progestational Compounds

NELLOR, JOHN E.

Jour. An. Sci. 19: 412-420. 1960. (Journal Article 2488 from the Michigan Agricultural Experiment Station)

The control of estrus and ovulation has been obtained in mature gilts by twice a day feeding of an orally active progestational compound. 1.6 mg of 6-methyl-17-acetoxyprogesterone per pound body weight by twice a day feeding resulted in complete inhibition of estrus and follicular growth during the treatment period. Estrus occurred, on the average 4.4 days from the end of treatment, and the start of estrus was synchronized within a 36-hour period. Autopsy following the controlled estrus demonstrated that ovulation had occurred.

Immature gilts receiving 1.6 mg of 6-methyl-17-acetoxyprogesterone for 10 days followed by the subcutaneous injection of 1000 I.U. of equine gonadotropin came into estrus within a 12-hour period 4 days following the gonadotropin injection. Autopsy 24 to 36 hours after the start of the induced estrus indicated that the follicular development and subsequent ovulation were normal.

Acceleration of Early Growth of Sugar Beets Seedlings by Coating of Seedballs with Hydrophilic Colloids and Nutrients

MIYAMOTO, TAKAO AND S. T. DEXTER

Agron. Jour. 52: 269-271. 1960. (Journal Article 2492 from the Michigan Agricultural Experiment Station)

Sugar beet seedballs were given a thin coating of a hydrophilic colloid (algin "Keltex", gelatin, agar, etc.) by immersing the seedballs in the colloidal solution and then drying. Such treatment accelerated the uptake of water and germination in comparison with untreated seed, but not the rate of growth. Addition to the colloidal solution of Hoagland's nutrient solution in 5 times normal concentration (less calcium nitrate) stimulated seedling growth without appreciably

slowing emergence. Treatment with Hoagland's solution in the absence of the colloid slowed emergence. Further addition of 1% sucrose and 0.05 to 0.45% asparagine to the colloid-mineral solution further stimulated the growth of seedlings appreciably when the treated and dried seed was planted in fertile clay loam soil. Growth of the roots was especially increased.

Variables Affecting Ratio Factors for Estimating 305-Day Production from Part Lactations

LAMB, R. C. AND L. D. MCGILLIARD

Jour. of Dairy Sci. 43: 519-528. 1960. (Journal Article 2502 from the Michigan Agricultural Experiment Station)

Complete lactations for 12,561 Holsteins, 2,262 Guernseys, 990 Jerseys, and 459 Brown Swiss recorded in Michigan DHIA-IBM from June 1954 through July 1957 were analyzed to ascertain the relative effects of breed, herd, age, parity, and season of freshening on the relationship of total to part milk production, and then were used to derive ratio factors for extending partial records to 305 days.

In practice breed, age, and season of freshening should be considered in extending partial records to 305 days.

Effect of Threonine Deficiency on Changes in Enzyme Activity and Liver Fat Deposition with Time

CARROLL, C.; D. ARATA AND D. C. CEDERQUIST

Jour. of Nutr. 70: 502-506. 1960. (Journal Article 2505 from the Michigan Agricultural Experiment Station)

Albino rats were fed a low protein diet (9% casein) deficient in threonine. The activities of several enzyme systems were measured at intervals over a period of 43 days. Control rats were fed the same diet supplemented with 0.36% of DL-threonine. The deposition of liver fat in the threonine deficient rats reached a peak in 24 days. After 6 weeks the level of fat in the livers of these rats had fallen to approximately half of this maximum.

The activities of two enzyme systems, xanthine oxidase and malic dehydrogenase, varied with time. The maximum decrease in activity of these systems in the threonine deficient group, as compared with the control, occurred on the 19th day of the experiment. This phase of decreasing activity was followed by a period of recovery.

Accuracy of a Lactometric Field Test for Measuring Solids-Not-Fat Content of Milk

LAMB, R. C.; L. D. MCGILLIARD AND J. R. BRUNNER

Jour. of Dairy Sci. 43: 491-495. 1960. (Journal Article 2510 from the Michigan Agricultural Experiment Station)

The solids-not-fat (SNF) content of milk can be measured with sufficient accuracy in the field by DHIA supervisors using the small Watson-pattern lactometer if readings are made at 102° - .5° F. In the first of two trials, comparisons between field and laboratory measurements showed small differences due to improper temperature control. No practical differences between field and

laboratory were observed in the second trial. The mean difference between lactometer readings in the field and in the laboratory was .28 lactometer degrees. Accuracy to .5 lactometer degrees is comparable to the accuracy of the Babcock test for fat. Correlations between field and laboratory tests, between duplicate samples in the field, and between duplicate samples in the laboratory were .964, .983, and .981, respectively, for the first trial and .968, .986, and .986, and .992, respectively, for the second trial.

Does Over-dominance Exist for Yield in Corn?

GRAFIUS, J. E.

Agron. Jour. 52: 361. 1960. (Journal Article 2514 from the Michigan Agricultural Experiment Station)

Evidence, based on a geometric model for yield, was presented which strongly indicates that over-dominance for yield in corn does not exist. This conclusion, if true, will have important implications in genetics and in breeding since the over-dominance hypotheses is essentially pessimistic in that it requires that undesirable allels be retained in the population.

Influence of Fertilizer Analysis and Placement on the Emergence, Growth, and Nutrient Absorption by Wheat Seedings in the Greenhouse

LAWTON, K. AND J. F. DAVIS

Agron. Jour. 52: 326-328. 1960. (Journal Article 2518 from the Michigan Agricultural Experiment Station)

Under greenhouse conditions, a high analysis complete fertilizer placed in contact with wheat seed severely reduced emergence and growth of seedlings. When the potash fraction of the fertilizer was mixed with the surface inch of soil, very little injury resulted from nitrogen and phosphate fertilizer placed with seed. Plant absorption of fertilizer phosphorus was highest from this placement. However, applying the fertilizer in a band 1½ inches below the seed or 1½ inches below and to the side of the seed resulted in a combination of maximum seedling growth and uptake of P^{32} labelled phosphate. Some reduction in seedling development and fertilizer phosphate absorption occurred when the fertilizer band was placed 3½ inches from the seed. Spraying fertilizer on the soil surface produced as vigorous plants as did other placements, but absorption of phosphate from fertilizer was reduced 40 to 50 percent.

Fertilizer Studies in the Cauca Valley of Colombia

LAWTON, K. AND E. PATINO

Soil Science Society of America Proceedings. 24. No. 3: 202-205. 1960. (Journal Article 2526 from the Michigan Agricultural Experiment Station)

Nine fertilizer experiments involving six major crops were conducted over a 2-year period in the Cauca Valley of Colombia. An area of moderate fertility for study was selected on a sloping outwash adjacent to the Andes Mountains.

With two similar experiments on corn conducted at the same time on different soil areas, marked yield response to phosphate fertilizer was obtained at one location, whereas at the second, neither nitrogen nor phosphorus were of

much benefit. A third experiment dealing with fertilizer, irrigation, and plant population showed that supplemental water and adjustment of stand were more important than fertilizer requirements in determining corn yields.

Substantial increases in yields of field beans and pangola grass were obtained with nitrogen, but not with phosphate fertilizers. With sugar cane, both phosphorus and potassium were required for high cane production.

Maintaining High Soil Nutrient Levels for Increased Yields of Greenhouse Tomatoes Without Excess Salt Accumulation

LUCAS, R. E., S. H. WITTWER AND F. G. TEUBNER

Soil Sci. Society of American Proceedings. 24. No. 3: 214-218. 1960. (Journal Article 2529 from the Michigan Agricultural Experiment Station)

Experimental and commercial plantings of greenhouse tomatoes received supplemental fertilizers in the form of monopotassium phosphate, diammonium phosphate and potassium and ammonium nitrate in quantities greater than normally applied. Monthly changes in soil nutrient levels and soluble salt contents were determined and crop behavior observed. A total of 2922 pounds of nitrogen, 3054 pounds of P_2O_5 and 4662 pounds of K_2O per acre were applied during two growing seasons in experimental plantings at the Michigan State University. Soil tests near the end of the growing season for the second year showed 10 pounds of nitrate - N, 188 pounds of P and 402 pounds of K per acre by the Spurway "active" method. The soluble salt reading for a 1-2 soil-water mixture was 28 x 10^{-5} mhos which is a very low reading. Yields up to 100 tons of fruit per acre were harvested resulting in total crop removal of 350, 105 and 580 pounds per acre of nitrogen, phosphorus and potassium. Cooperative studies were conducted with seven commercial growers. The fertilizer program followed closely that used at the university. Results of soil tests and soluble salt readings were similar to those obtained at the university greenhouse.

Investigation of the Oxidation-Reduction Potential of Rumen Contents

BALDWIN, R. L. AND R. S. EMERY

Jour. of Dairy Sci. 43: 506-511. 1960. (Journal Article 2530 from the Michigan Agricultural Experiment Station)

The relationship between the E_h and pH of rumen fluid was found to be represented by the equation $E_h = E_o$ -0.06 pH. Investigation of the reductive capacity of rumen fluid removed from cows on various rations indicated:

1. A very small proportion of the reduced substances found in rumen fluid are associated with the bacterial cells.
2. The amount of reducing substances is significantly higher several hours after feeding them at other times during the day.
3. There is a definite relationship between the ration fed and the reducing capacity of rumen fluid removed at different times during a 24-hour period. This relationship is in agreement with the fact that no concentrates are digested more quickly than roughages.

On the basis of the above observations, it is proposed that the reductive characteristics of rumen fluid can be used as an index of fermentation rate in much the same manner in which pH is presently used.

Convection in Syrup-Packed Products

Nicholas, R. C., I. J. Pflug and T. R. Mulvaney

Food Tech. 14: 205-207. 1960. (Journal Article 2547 from the Michigan Agricultural Experiment Station)

This paper presents a method of calculating a criterion of no convection in syrup-packed products and presents evidence to suggest how this criterion is related to the difficulty of heating syrup-packed products in which productincuce stratification has occurred.

Product-Induced Stratification of Covering Syrups

Mulvaney, T. R.; R. C. Nicholas and I. J. Pflug

Food Tech. 14: 207-212. 1960. (Journal Article 2548 from the Michigan Agricultural Experiment Station)

The results of this study indicate that when a high-moisture food is placed in a sugar solution, the water leaving the product does not diffuse uniformly into the syrup throughout the jar, but instead rises to the top thereby giving rise to a density gradient. This stratification begins as soon as the syrup is added to the product, and, moreover, is little affected by the pasteurization process. This paper describes the details of the formation of this density gradient in sweet fresh cucumber pickles and the gradual decrease in the magnitude; gradient as syrup and product approach equilibrium.

Convection Heating Studies of Water-Syrup Layered Systems

Nicholas, R. C., I. J. Pflug and T. R. Mulvaney

Food Tech. 14: 213-214. 1960. (Journal Article 2549 from the Michigan Agricultural Experiment Station)

This paper presents the results of a study of the heating characteristics in a model system constructed of layers of syrup and water. It is shown that no liquid is transferred across the syrup-water interface and that the large density difference between these layers has significantly increased the difficulty of heating such a system.

Effects of High Temperature Storage on the Quality of Fresh Cucumber Pickles

Nicholas, R. C. and I. J. Pflug

The Glass Packer, April, 1960. (Journal Article 2551 from the Michigan Agricultural Experiment Station)

The extent of deterioration of three different fresh cucumber pickle products as a function of storage time and temperature was measured subjectively on the basis of appearance, flavor, and texture. The results, covering a storage time of over a year and several temperatures from 40° F. to 100° F. show that the deterioration rate is a function of temperature. The basic recommendation derived from these results is to cool the product as quickly as possible after pasteurization and to keep it cool. A method is described for predicting quality as a function of storage condition.

Measurement of Product Attributes Recognized by Consumers

SMITH, VICTOR E.

Center for Agricultural and Economic Adjustment, Report No. 5, Iowa State University, Ames, Iowa, April, 1960. (Journal Article 2564 from the Michigan Agricultural Experiment Station)

A food is a collection of the utilities obtained from the nutrients it contains and the utilities derived from the specific taste or habit preferences it satisfies.

If we have a linear programming model which is descriptive of a consumer's motivations and leads to the diet which she voluntarily chooses to buy, we can decompose each bundle of utilities into its several parts and assign marginal values to each utility.

Each such value equals the smallest payment necessary in order to obtain an increment in one utility alone.

For the hypothetical consumer described by the model used in this paper, sample results are as follows:

Marginal Utilities in Terms of Money
(Cents per Pound of Food)

Food	Total Nutrients	Specific Taste or Habit Preference	Price of Food
Fresh Oranges	1.7	9.1	10.8
Head Lettuce	1.0	25.9	26.9
Wieners and Franks	8.5	44.5	53.0
Bacon	18.7	33.1	51.8
Hominy	10.2	0.0	10.2

Bloat Versus No Bloat in Identical Twin Cows Fed Identical Rations

EMERY, R. S.; C. K. SMITH; C. W. DUNCAN AND H. M. SELL

Jour. of Dairy Sci. 43: 568-569. 1960. (Journal Article 2568 from the Michigan Agricultural Experiment Station)

One member of each of 2 pairs of identical twins was fed a ration of 16 lb. of a grain mixture plus 4 lb. hay until frothy bloat was established. Meanwhile, the other member of each pair was fed hay. At the end of this preliminary period, all cows were fed a ration of 10 lb. grain and 10 lb. hay which maintained but would not establish bloating. The concentration of lipid and nitrogenous constituents was greater in the clarified rumen liquid from the bloated cows. The pH of rumen contents was also lower in the bloated cows. The role of these differences in the etiology of bloat remains to be determined.

An Apparently New Root Necrosis Disease of Rhubarb

MURAKISHI, HARRY H.

Plant Disease Reporter 44: 186-188. 1960. (Journal Article 2583 from the Michigan Agricultural Experiment Station)

A root necrosis disease affecting rhubarb (*Rheum rhaponticum* L.) in southeastern Michigan was found to be caused by an unidentified, septate, non-

sporulating fungus. Symptoms reproduced in the greenhouse consisted of stunting, chlorosis, wilting of the lower leaves and necrotic streaks in the vascular tissue 3-6 weeks following inoculation. Although similar in symptoms to Verticillium wilt, the fungus in question did not attack known suscepts of Verticillium such as tomato, eggplant and pepper.

Induction of Staminate Flowers on Gynoecious Cucumbers with Gibberellin A_3

PETERSON, C. E. AND LAMOINE D. ANHDER

Sci. 131: 1673-1674. 1960. (Journal Article 2626 from the Michigan Agricultural Experiment Station)

Staminate flowers were induced on gynoecious cucumber plants by foliar applications of gibberellin A_3. There was a wide range of effective induction treatments and gynoecious plants displayed a high degree of tolerance to the chemical. Three or four applications of gibberellin A_3 at 1500 ppm at weekly intervals beginning when the first true-leaf was expanded to 1 inch diameter induced ample pollen for increasing gynoecious inbreds under isolation cages.

This method of altering sex expression has important practical application in the development of commercial F_1 hybrids. Homozygous gynoecious lines developed by this method will be useful in studying the genetics and physiology of sex expression.

Initation of Lactation in Rats by Nonspecific Stresses

NICOLL, CHARLES S., P. K. TALWALKER AND JOSEPH MEITES

Amer. Jour. of Physiology. 198. No. 5: 1103-1106. 196. (Journal Article 2535 from the Michigan Agricultural Experiment Station)

Sixty mature, virgin female rats were divided into six groups of ten each and injected subcutaneously for ten days with 10 μg estradiol in 0.1 cc corn oil. For the following five days the groups were treated as follows: (1) controls, 0.1 cc saline injected subcutaneously once daily; (2) severe cold (O° C) 24 hours per day; (3) intense light and heat for 12 hours per day; (4) restraint, 12 hours per day; (5) starvation, no food or water for five days; (6) subcutaneous injection of 0.1 cc or 0.2 cc of 10 percent formaldehyde once daily. The mammary glands of the control rats regressed from a lobulo-alveolar system to a bare duct system during the period of saline injections. The stressed groups all showed variable degrees of lactation after treatment. It is concluded that nonspecific stresses can promote the secretion of prolactin and ACTH from the anterior pituitary in amounts adequate to induce lactation in estrogen-primed rats. The possible role of stresses in initiating lactation at parturition and under other circumstances is considered, and a common mechanism controlling the secretion of ACTH and prolactin is postulated.

A Strain of Tobacco Mosaic Virus Associated with a Wilt and Stem Necrosis of Mature, Field-Grown Bell Pepper

MURKISHI, HARRY H. AND SHIGEMI HONMA

Plant Disease Reporter. 44: 550-551. 1960. (Journal Article Number 2634 from the Michigan Agricultural Experiment Station)

A strain of tobacco Mosaic virus was isolated from mature pepper plants affected with wilt and stem necrosis. Wilt symptoms were reproduced in the

greenhouse on Penn-Wonder-Allbig and Sunnybrook plants seven to eight weeks following inoculation. The susceptibility to stem necrosis and wilt in the hybrid was probably derived from Penn Wonder which was the female parent. Allbig, the male parent showed local necrotic symptoms but no stem lesions or wilt in contrast to the extreme susceptibility of Penn Wonder.

Induction of Lactation and Mammary Growth by Pituitary Grafts in Intact and Hypophysectomized Rats

MEITES, JOSEPH AND T. F. HOPKINS

Proc. Soc. Exper. Biol. and Med. 104: 263-266. 1960. (Journal Article Number 2617 from the Michigan Agricultural Experiment Station)

1. Sixty mature female rats were injected with 10 μg estradiol daily for ten days to develop their mammary glands. On days 1, 5, or 7, all except ten control rats were each implanted underneath the kidney capsule with a pituitary from a similar untreated donor rat; on day 11, twenty-six implanted rats were hypophysectomized. All rats were killed on day 16. 2. Control mammary glands regressed to a bare duct system and showed no secretion, whereas twenty-three of twenty-four intact rats were pituitary grafts and twelve of twenty-six hpyophysectomized rats with grafts showed mammary secretion and/or lobule-alveolar development. Most rats with pituitary implants had ovaries with large corpora lutea and few or no follicles. These results demonstrate that grafted pituitaries in the rat secrete greater than normal amounts of prolactin.

Induction of Mammary Growth and Lactation in Rabbits with Epinephrine, Acetylcholine and Serotonin

MEITES, JOSEPH; P. K. TALWALKER AND C. S. NICOLL

Proc. of the Soc. for Exper. Biol. and Med. 104: 192-194. 1960. (Journal Article Number 2593 from the Michigan Agricultural Experiment Station)

1. Thirty-eight mature female, predominantly New Zealand White rabbits, were injected subcutaneously daily with 0.2 mg estradiol for fifteen days to develop the mammary duct system. They were then divided into four groups and injected subcutaneously as follows for five days: 0.85% saline; 0.25 mg epinephrine in oil twice daily; 12.5 mg acetylcholine iodide/kg BW twice daily; 5 mg serotonin base/kg BW once daily. On the twenty-first day the rabbits were killed and mammary glands examined for growth and lactation. 2. Only one of eleven saline-injected rabbits showed gross lactation and lobuloalveolar development, in contrast to six of eight epinephrine-treated rabbits, five of eight acetylcholine-injected rabbits and nine of eleven rabbits treated with serotonin. The latter drug induced the greatest, and acetylcholine the least degree of mammary growth and lactation. 3. These results demonstrate that the three drugs in pharmacological doses can induce prolactin release from the anterior pituitary of rabbits.

The Quarterly Bulletin

The Quarterly Bulletin of the Michigan Agricultural Experiment Station is issued in February, May, August and November. It presents progress reports on long-term major research projects and final reports on short-term projects.